

BBC

WHAT CAN COSMIC RAYS TELL US ABOUT THE PYRAMIDS?

FOCUS

SCIENCE AND TECHNOLOGY

UNLOCKING THE SECRETS OF THE BRAIN

How 'minibrains' being grown in labs could reveal what makes us human



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WELCOME



Allow me to borrow one of many great quotes from Douglas Adams: "If you try and take a cat apart to see how it works, the first thing you have on your hands is a nonworking cat". Adams was talking about the ineffable nature of life itself, but I think his words apply pretty well to the study of our brains. While dissections, scans and experiments have taught us a huge deal about the brain and its underlying structures and functions, we're

still left with some gaping holes in our knowledge. For instance, we know most of the population uses the left hemisphere of their brain to handle language, but we don't know why that's the case. We understand, to a degree, what changes in brain function lead to autism spectrum disorder, but we don't fully understand what causes these changes in the first place. This is where 'minibrains' come in. They start life as a bunch of skin cells which are bathed in some genes that effectively hit a cellular rewind button, turning them back into stem cells, the putty from which life is made. These are then nurtured into brain cells which, with a little encouragement, coalesce into grey matter. As they develop, their growth is recorded (and in some cases their genes altered) to reveal piece-by-piece how our brain works. Think of it like taking apart a mechanical watch and putting it back together – forgot to put out a cog back in, and you'll find out why it was useful in the first place. This is opening up a whole new way to understand the brain and how it works – find out what's being uncovered on p38.

Have a great Christmas (and find out how to really nail it on p48).

Daniel Bennett

Daniel Bennett, Editor

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CHRISTMAS 2017



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Special issue



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She's having a bubble!

KEDAH,
MALAYSIA

This is a social wasp belonging to the genus *Ropalidia*, which is commonly found across southeast Asia. Most insects belonging to this genus produce nests by swarming, in a manner similar to honeybees – an unusual behaviour for wasps. However, in this particular species, a single mated female starts a nest in much the same way that wasps in the UK do.

"In this photo, the female has constructed a paper nest from wood fibres and water – natural papier maché – and in the cells you can see developing larvae. These will turn into adult females that look exactly like their mother queen, but instead of laying eggs, they will become workers, expanding and defending the nest and tending to the eggs and larvae," said entomologist and BBC presenter Adam Hart. "She has removed water from the open nest using her mouth. Wasps, like their relatives the bees and ants, are scrupulous in keeping conditions in their nests just right for rearing the young."

Unlike worker wasps in the UK, which remain more or less sterile throughout their lives, *Ropalidia* workers have the capacity to become breeding females that can replace the mother queen if she is lost.

PHOTO: CATERS NEWS



EYE OPENER

A nifty little mover

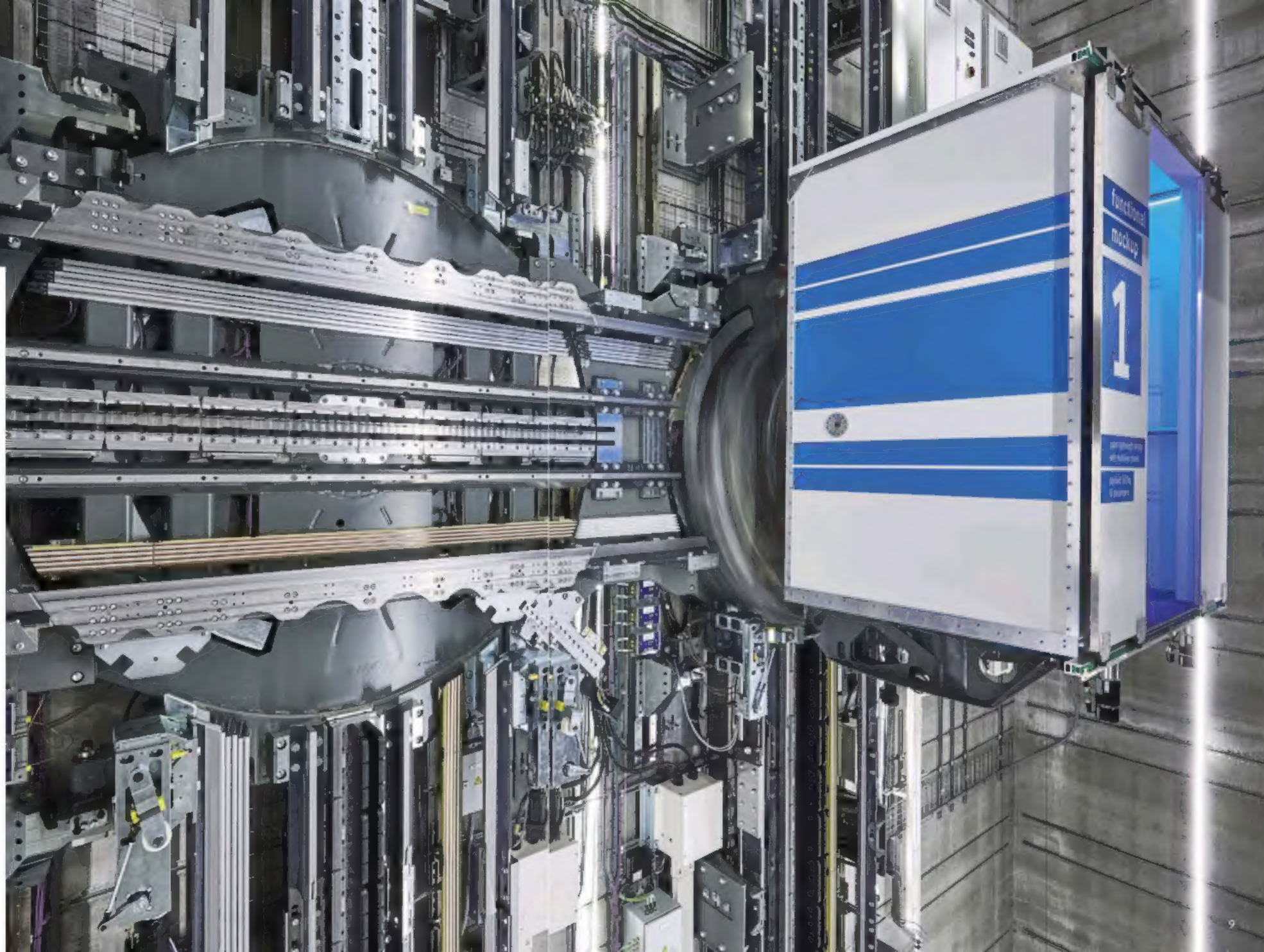
ROTTWEIL,
GERMANY

Looking like something out of Willy Wonka's chocolate factory, this image from ThyssenKrupp's testing tower shows the world's first 'ropeless' elevator. Thanks to its cable-free design, the MULTI elevator can move both vertically and horizontally, with exchanger mechanisms controlling direction, much like points on a railway line.

Very tall buildings require multiple lift shafts, as having a single, central shaft can undermine their structural integrity. But as Markus Jetter, ThyssenKrupp's head of project development, explains: "With MULTI lifts, architects are no longer restricted in their designs by concerns about elevator shaft height and vertical alignment. Traditional shafts can occupy 40 per cent of the floor space in a typical tall building; MULTI halves that, leaving more room for offices and apartments."

The first MULTI elevator is due to be installed in the new East Side Tower in Berlin in 2020.

PHOTO: THYSSENKRUPP



REPLY

Your opinions on science, technology and *BBC Focus*

MESSAGE OF THE MONTH

SLEEP STRUGGLES

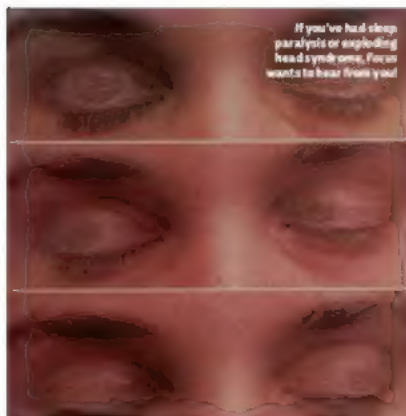
This morning my mother sent me your survey on sleep paralysis and a condition that I was not aware of, exploding head syndrome, which sounds terrible. I completed the survey and added myself to the optional list at the end with the hope of maybe hearing some of your findings. I have suffered from sleep paralysis since I was a child, and at least three or four times a week. I got it the worst when overtired and just lying down for bed.

My father is a doctor who specialises in the diagnosis of epilepsy and other neurological conditions. My question to you, I suppose, is in regards to my father's explanation of how sleep paralysis works and whether he is right. Dad told me that when you fall asleep your body goes into a state of sleep called REM (rapid eye movement) where by your eyes are darting around behind your eyelids as you dream.

The problem with this is that if this happened every time we went to sleep we would be kicking, punching, walking around, you name it when we are completely asleep. So to combat this the body essentially disconnects its brain from its central nervous system as a preventative measure. According to Dad, sleep paralysis is when your brain is awake but remains cut-off from your central nervous system. He also went on to explain that this also accounts for people's description of seeing demons or aliens, as they are not completely awake and remain partially asleep.

I have never had such an experience as that. I can only open my eyes and control my breathing, I can however pull myself out of it, and my girlfriend will shake me awake which works.

Matthew Haindl, Sydney, Australia



If you've had sleep paralysis or exploding head syndrome, Focus wants to hear from you!

I'm glad to hear you found our survey (anyone that hasn't can do so at scienceofocus.com/bigsleepsurvey). Your dad is essentially right: sleep paralysis happens when a person wakes up before REM sleep is finished. Your body's ability to move hasn't been switched on yet – even though you're conscious. In some cases, this combination can fuel hallucinations of witches, ghosts and ogres. The NHS (www.nhs.uk/conditions/sleep-paralysis) is a good resource if you want to find out more. Plus, keep an eye on scienceofocus.com for our follow-up piece... *Dan Bennett, Editor*

WRITE IN AND WIN

The writer of next issue's Message Of The Month wins a bundle of science-themed socks courtesy of **Chatty Feet**. Ada Hovav, Brian Cox, Albert Einstein and Stephen Hawking will keep your feet nice and snug this winter, and they'll throw in the film-themed Bad Ass gift set to boot! chattyfeet.com



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FAREWELL

I was saddened to read that this month's edition carried Robert Matthews' last column for the magazine (November, p31). I've been a subscriber for many years, and this was the column I'd often turn to first. Please forward my thanks for many years of enjoyable and thought-provoking comment. Steve, via email

HEADLINE NEWS

I feel the need to hold Russell Deeks to account on a few points in his reply to Roger Britton's Message Of The Week (November, p14). Cards on the table – I am a music lover and audiophile who prefers CD, though agnostically. I prefer the convenience and the fact that discs do not wear rather than possessing an 'ideological' view.

Russell perpetuates a myth or two, and is rather vague in his arguments. Most people know that CD's original sampling rate was set because theory suggested that higher frequencies were inaudible and therefore irrelevant. The opinion that this was a mistake and that inaudibly high frequencies did affect what we hear gained ground steadily, and SACD and DVD-Audio were created to address this weakness. The latter went nowhere, and large scale double-blind testing has shown that even discerning listeners cannot tell the difference between CD and SACD (I own SACDs and I certainly can't) with the caveat that at high volumes, a lower noise floor exists in SACD. I am therefore deeply sceptical about the claim that "much of the harmonic information is lost" in CD. I would suggest that in using imprecise terminology and

hinting at lost 'harmony', this is an appeal to the heart, not the head.

And if sampling rate beyond CD-grade is not audible, the fact that much of today's vinyl was originally recorded in digital form is perhaps best not contemplated too much...

I also cannot tell the difference between CD copies taken from vinyl and the original source, suggesting either that there is no magic that doesn't translate into ones and zeros, or that I am clothed beyond redemption. I have no reason to believe the latter! Simon Bartlett, via email

Nearly all music today is indeed recorded digitally, but Simon conveniently overlooks the fact that nearly all modern studios have also moved to 24-bit/96kHz recording as a minimum – partly because this enables more of those 'inaudible' frequencies to be heard! As for the 16-bit/44.1kHz sampling rate for CD, as I understand it this rate was chosen not because "higher frequencies were inaudible and therefore irrelevant," but because such a rate would allow a 60-minute album to fit onto one 10.5cm disc – the initial size proposed for CDs. This was later increased to 12cm to allow a playback time of 74 minutes – long enough for Beethoven's 9th Symphony to fit onto one disc.



Simon Bartlett says CD is as good as sound can get

However, as I said last month, what any of us can or can't hear is entirely subjective – we certainly aren't suggesting Mr Bartlett should replace his CDs if he doesn't want to! Russell Deeks, contributing editor

Following Robert Matthew's column on Goodhart's Law (October, p23), we enjoyed this illustration by @sketchplanator on Twitter, which explains the idea perfectly!

GOODHART'S LAW

WHEN A MEASURE BECOMES A TARGET, IT CEASES TO BE A GOOD MEASURE

IF YOU MEASURE PEOPLE ON...

NUMBER OF NAILS MADE

WEIGHT OF NAILS MADE

THEN YOU MIGHT GET

1000'S OF TINY NAILS

A FEW GIANT, HEAVY NAILS



sketchplanations

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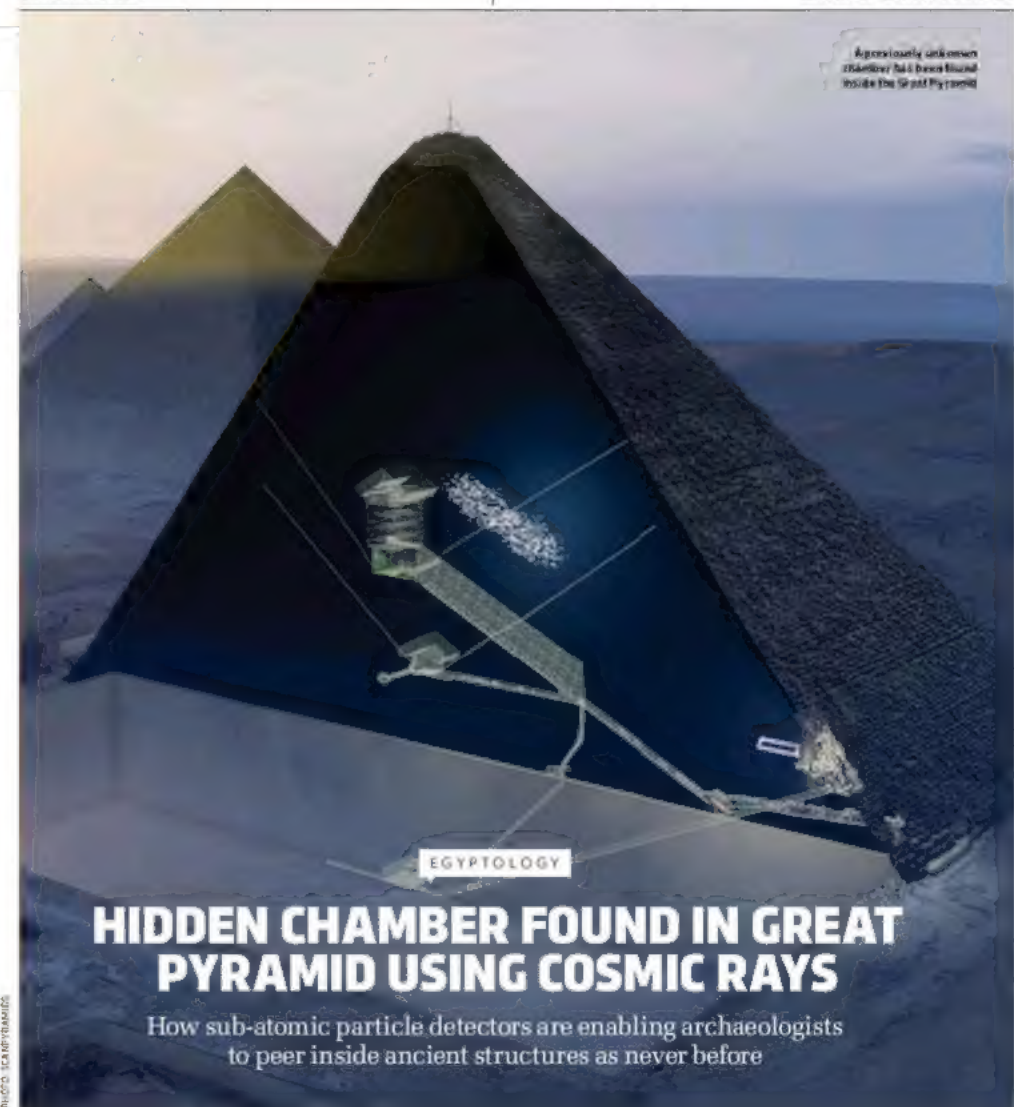
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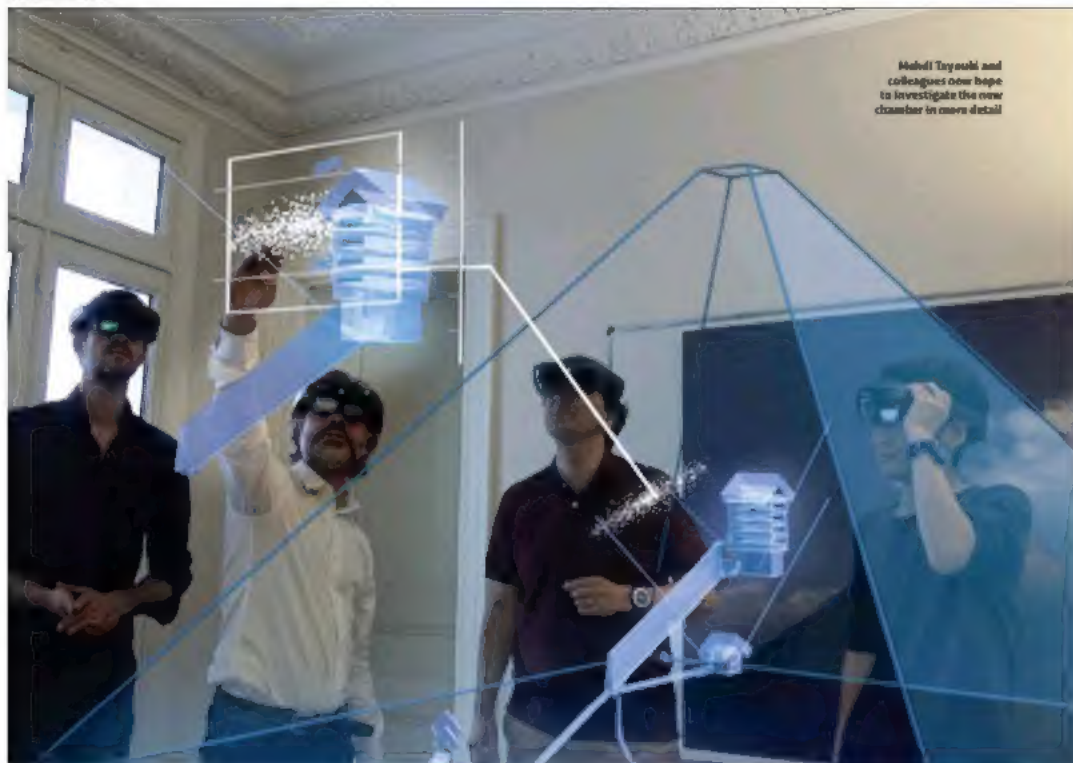
DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

CHRISTMAS 2017

EDITED BY JASON GOODYER





Mehdi Tayoubi and colleagues over hope to investigate the new chamber in more detail

Archaeologists have uncovered a mysterious chamber deep within the Great Pyramid of Giza, using a cutting-edge imaging technique based on the detection of subatomic particles created by cosmic rays.

Dubbed the ScanPyramids Big Void, after the name of the project that discovered it, the cavity is approximately 30m long and 3m high and is situated above the Grand Gallery, a large corridor that connects the two largest of the iconic structure's three main chambers.

The Great Pyramid, also known as Khufu's Pyramid, was built during the reign of Pharaoh Khufu, who reigned from 2509 to 2483 BC. Despite years of research, there is no consensus on exactly how the monument was constructed.

As yet the precise structure and role of the newly discovered void remain unknown, but the findings may pave the way for further studies that could help researchers to understand the pyramid and its construction process.

"No important internal structures have been found in the Pyramid since 820AD, when the Calife

"OUR DISCOVERY IS THE FIRST DEMONSTRATION OF THE POTENTIAL OF COSMIC RAY IMAGING TO GATHER NEW INFORMATION IN ARCHAEOLOGY"

Al Mamun dug a tunnel and penetrated inside, revealing most of the structure we know today," said Prof Mehdi Tayoubi from Cairo University. "Finding something as important, in terms of size, as the Grand Gallery is an important breakthrough."

The void was discovered using sensors tuned to detect muons, particles that are created when high energy cosmic rays slam into molecules in the upper atmosphere. By piecing together data from several different locations, the team were able to form a three-dimensional image of the pyramid's internal structure.

"Our discovery is the first demonstration of the potential of cosmic ray imaging to gather new information in archaeology," said Nagoya University's Kunihiro Morishima. "The Big Void has not been touched by anyone since the building of the pyramid 4,500 years ago, so if there are some artefacts inside the big void, they should be very important for understanding ancient Egypt."

The team now plan to take further scans of the Big Void, in order to determine its shape and structure in more detail.

PHOTOS: SCANPYRAMIDS, SCIENCE PHOTO LIBRARY, ILLUSTRATION: KAZ

WHAT ARE MUONS?

Muons are negatively charged subatomic particles that come from the lepton family – the same family as electrons, though muons are much heavier. Like electrons, they are not thought to be made up of any smaller particles, making them a so-called elementary particle. They were first discovered in 1936 by Nobel Prize-winning physicist Carl Anderson and Seth Neddermeyer at Caltech in the US while they were studying cosmic radiation.

Around 10,000 muons reach every square metre of the Earth's surface each minute. They are created when cosmic rays – high energy radiation that originates from outside the Solar System – collide with molecules in the upper atmosphere. As muons don't interact very strongly with matter, they are able to travel through solid objects – including our own bodies – and penetrate deep into the surface of the Earth.

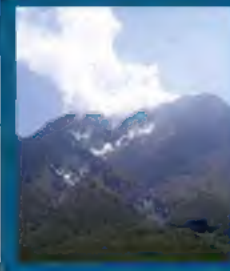


Cosmic rays from outside our Solar System send muons cascading through it

WHAT IS MUON TOMOGRAPHY?

Thanks to their ability to penetrate deep into solid matter, muons can be used to image the internal structure of objects in a manner similar to X-rays. Detectors are placed in strategic positions around the object to be scanned, and left running for several months. Over time a pattern of detections builds up, revealing the void areas where the muons passed through without issue, and the denser areas where some of them were absorbed or scattered. The internal structure of the object can therefore be discerned.

The technique has previously been used to reliably image and create 3D models of the interior of volcanoes, making clear the distinction between rocks of different temperatures, water, and voids beneath the surface, and also to probe the ruins left behind in the wake of the Fukushima Daiichi nuclear disaster.





ZOOLOGY

COCKATOOS ARE SKILFUL SHAPE-SORTERS

Who's a clever boy, then? Goffin's cockatoos, a species of small parrot native to Australasia, have been shown to have similar shape-recognition abilities to a human two-year-old.

Though not known to use tools in wild, the birds have proved adept at tool use in captivity. In a recent experiment at the University of Vienna and the University of Veterinary Medicine Vienna, cockatoos were presented with a box with a nut inside it. The clear front of the box had a 'keyhole' in a geometric shape, and the birds were given five differently shaped 'keys' to choose from. Inserting the correct 'key' would release the nut.

In humans, babies can put a round shape in a round hole from around one year of age, but it will be another year before they're able to do the same with less symmetrical shapes such as squares, triangles or crosses. This ability to recognise that

a shape will need to be rotated into a specific orientation before it will fit is called an 'allocentric frame of reference'. In the tests in Vienna, the Goffin's cockatoos were able to select the right tool for the job, in most cases, by visual recognition alone. Where trial-and-error was involved, the cockatoos fared better than apes and monkeys have in similar tests.

"This indicates that [Goffin's cockatoos] do indeed possess an allocentric frame of reference when moving objects in space, similar to two-year-old toddlers," said Alice Auersperg, head of the Goffin lab at the University of Veterinary Medicine Vienna.

The next step, say the researchers, is to try and work out whether the cockatoos rely entirely on visual clues, or also use a sense of touch in making their shape selections.

Goffin's cockatoos have shape-recognition abilities akin to those of a human two-year-old

PHOTOS: BENEDICT LUTTY

PALAEONTOLOGY

DINOSAUR-KILLING ASTEROID IMPACT WAS WORSE THAN WE THOUGHT

Some 66 million years ago, an asteroid struck the Yucatan peninsula in Central America, forming the Chicxulub crater and wiping out the dinosaurs in what is known as the Cretaceous–Paleogene (K–Pg) extinction event. But two new pieces of research suggest that this impact was even more cataclysmic than was previously believed.

A new study published in the journal *Geophysical Research Letters* shows that up to three times as much sulphur may have been released into the atmosphere as a result of the impact than previous models have suggested. This would have led to a longer period of global cooling, which helps to explain the devastating effects on the Earth's fauna at the time.

"Many climate models can't currently capture all of the consequences of the Chicxulub impact, due to uncertainty in how much gas was initially released," said the paper's lead author Joanna Morgan, a

geophysicist at Imperial College London. "We wanted to revisit this significant event and refine our collision model to better capture its immediate effects on the atmosphere."

But perhaps more surprising are the results of a study conducted at Japan's Meteorological Institute and Tohoku University. In a paper just published in the journal *Nature*, researchers Kunio Kaiho and Naga Okitama show that the high levels of soot and sulphurous gas that caused the mass extinction were a result of the rocks on the peninsula being particularly rich in hydrocarbons. Such rocks covered only around 13 per cent of the world's surface, and had the impact occurred in a different area where the rocks were less rich in hydrocarbons, the dinosaurs would most likely have survived.

In other words, the chances of the asteroid impact killing off the dinosaurs as it did were only slightly more than one in 10. Unlucky...



If the Chicxulub meteor had shifted trajectory slightly, dinosaurs could still be roaming the Earth today

IN NUMBERS

SIX MONTHS

The average time it takes to shed extra pounds put on through over-indulging during the holiday period, as estimated by a team at Tampere University, Finland.

23 TERAWATT HOURS

The amount of energy used globally by Bitcoin miners each year. That's just short of the 24.8 terawatt hours generated by renewable energy worldwide in 2016.

20 MILLION

The number of lives saved worldwide by the measles vaccine since the turn of the millennium, as calculated by the Centers for Disease Control and Prevention.

PSYCHOLOGY

"People who tended to mind-wander have more efficient brains"

It's usually considered bad when your mind wanders. But research by Dr Eric Schumacher of Georgia Tech suggests 'mind-wandering' means your brain has enough cognitive capacity to multi-task

What's the difference between daydreaming and mind-wandering?

Researchers are interested in identifying different types of what are called 'off-task behaviours'. Mind-wandering is a coherent train of thought – you might be thinking about the fact that you have to pick up your dry cleaning, pick up the kids from school, feed the dog. Whorish daydreaming is not goal-directed – a creative endeavour, thinking about things that don't exist. We were interested in other abilities that relate to the tendency to mind-wander.

How did you measure mind-wandering?

We gave over 100 participants questions like, 'On the bus, do you think about what you had for breakfast?' All of our minds tend to wander sometimes, but there are individual differences. So we measured brain activity at rest: we put participants in an MRI scanner and had them lie there in the dark, staring at a plus sign on a screen, for about 10 minutes. Their minds were probably wandering at that time.

Which brain circuits are involved?

MRI scans are useful for identifying networks of brain regions that work together to carry out behaviour. One is the 'default mode network', a collection of regions in the middle-front and middle-back part of your brain related to 'internally-focused attention'. When you're thinking about memories or your mind is wandering, those regions are more active. One of the measures we had was how connected that default mode network was.

What did you find out?

There's an idea that when your default mode network is connected and active at rest, your brain is likely to be more efficient at other times. To test this idea, we had subjects perform the 'remote associates' task, a measure of creativity. Participants are given three words and have to identify a word that links them together – for instance, they might see the words 'widow', 'monkey' and 'web', and they have to think of the word 'spider'.

We also had a measure of fluid intelligence, the ability to solve problems, called Raven's advanced progressive matrices task. In this test, you get given eight shapes and have to identify the ninth one that would fill in the pattern.

ABOVE: Letting your mind wander may not be such a bad thing after all

Our key finding was that people who tended to mind-wander more during their daily lives tended to have more efficient brains – they tended to score higher on the creativity and fluid intelligence tasks. What we show is that there may be times when our minds wander that's not necessarily maladaptive. We can think about other things that are important while also monitoring the task at hand, and switch back without much of a detriment in understanding or performance. It's not an explicit decision, just something our information-processing system is aware of, and allocates [mental] capacity to achieve our many goals.

So if mind-wandering isn't a bad thing, could it actually be good for you?

We would need to know much more. Can we measure an individual's intelligence, their creativity? Then we might be able to say: is their mind-wandering maladaptive or adaptive? For now, a practical implication of this research might be that if a person finds themselves mind-wandering a lot and they're still getting good grades in school, still performing efficiently at work, then maybe they shouldn't worry about the fact that sometimes they find themselves mind-wandering.

THEY DID WHAT?!



SHEEP TRAINED TO RECOGNISE CELEBRITIES

What did they do?

A team at the University of Cambridge placed eight sheep in a pen, one at a time. At one end, they displayed two photographs on computer screens – one of a celebrity and one of a random person – and placed infrared detectors on each of them. The celebrities used were Fiona Bruce, Jake Gyllenhaal, Barack Obama and Emma Watson. When the sheep moved towards the celebrity photograph they received a food reward. If they chose the wrong photograph, a buzzer would sound and they would receive nothing.

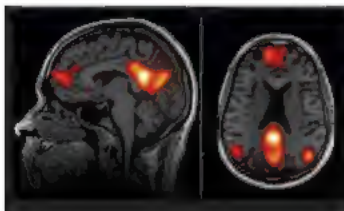
What did they find?

After training, the sheep were able to choose the photograph of the celebrity face eight times out of ten from the front, and around seven times out of ten when show the face from the side.

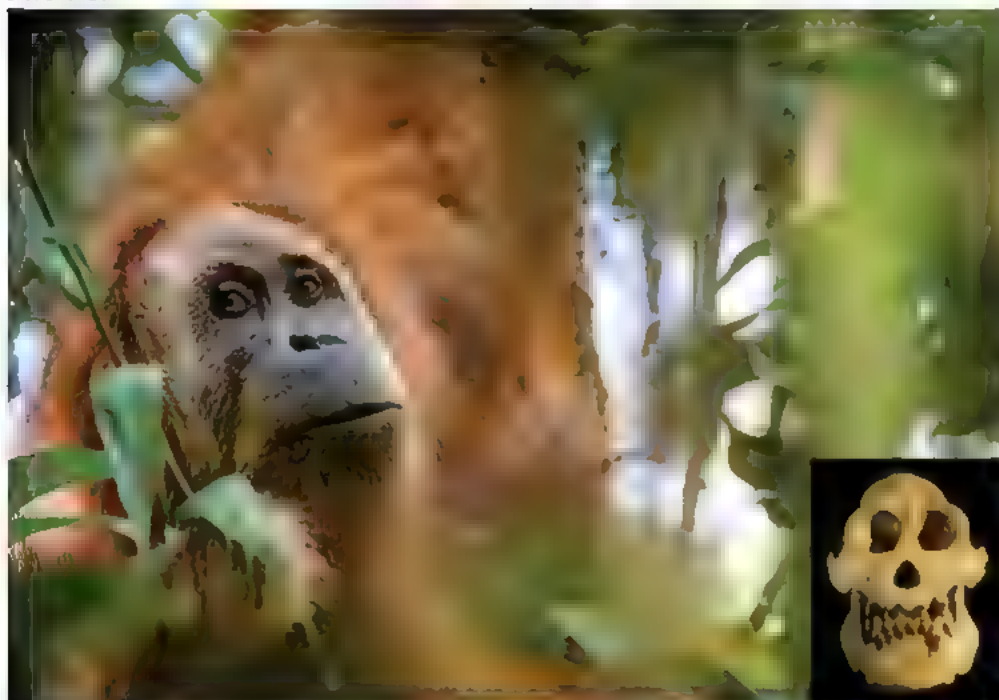
Why did they do that?

"Sheep are long-lived and have brains that are similar in size and complexity to those of some monkeys. That means they can be useful models to help us understand disorders of the brain, such as Huntington's disease, that develop over a long time and affect cognitive abilities," said study leader Prof Jenny Morton.

BELOW: The brain's 'default mode network' has previously been linked to daydreaming



PHOTOS: SHUTTERSTOCK (JONAS/SHUTTERSTOCK) (DAN BERNET)



ZOOLOGY

NEWLY IDENTIFIED ORANGUTAN IS WORLD'S MOST ENDANGERED GREAT APE SPECIES

A population of orangutans that lives in a remote part of northern Sumatra, and that was only discovered in 1997, has now been identified as a separate species. With only around 800 individuals known to exist, it's now among the most threatened of all great ape species.

It was once believed that all orangutans were one species, but since 1996 science has recognised two: the Bornean and Sumatran orangutan (*Pongo pygmaeus* and *Pongo abelii*, respectively). The following year, a long-removed population of orangutans living in the Batang Toru region of northern Sumatra was seen for the first time, but initially the apes were thought to be of the species *P. abelii*.

However, close study of an adult skeleton found in 2013 has revealed significant differences in the skull and teeth of the Batang Toru apes, leading to

their new classification: *Pongo tapanahensis* – or the Tapanuli orangutan. Genomic analysis suggests that the species must have split from *P. abelii* around 70,000 years ago.

"The Batang Toru orangutans appear to be direct descendants of the initial orangutans that had migrated from mainland Asia, and thus constitute the oldest evolutionary line within the genus *Pongo*," said lead author Alexander Nater from the University of Zurich.

With just 800 individuals known, *P. tapanahensis* goes straight to the top of the world's most endangered great apes league table, not least because large areas of its habitat are threatened by plans to build a hydroelectric dam in the region. The discovery isn't great news for *P. abelii* in that regard either – there are now 800 less of them than was previously believed.

Closer examination of a skeleton found in 2013 has revealed that *P. tapanahensis* is a separate species.

PHOTO: ANDREW WALSH/REUTERS; ILLUSTRATION: JAMES HUNTER/STOCK; ARTIST: DANIEL BUCK

SPACE

MASSIVE NEW EXOPLANET SHOULDN'T, IN THEORY, EXIST

Well, this is a bit of a headscratcher. Recently discovered exoplanet NGTS-1b is causing astronomers to rethink their ideas about how planets come into being, because according to current theories, such a large planet should not be able to form around a star as small as its parent.

NGTS-1b is the first exoplanet discovered by the first international Transiting Survey. This international initiative, based at the Paranal Observatory in Atacama, Chile, uses an array of 12 telescopes to scan a small area of sky repeatedly over several months. By detecting a dip in brightness, every 2.85 days, of the light coming from a red dwarf star dubbed NGTS-1, astronomers were able to determine that a 'hot Jupiter'-type exoplanet was orbiting the star.

'Hot Jupiters' are gas giants (like our own Jupiter) which are much closer to their parent star than Jupiter is to our own Sun, because

they're so large and orbit their parent so closely, they cause significant, regular dips in its brightness, and as a result are among the easiest exoplanets to spot. It's believed they form like Jupiter, in the outer reaches of a solar system, before migrating inwards – but such an explanation assumes the presence of a much bigger star than our own Sun. According to current theories, a red dwarf like NGTS-1, which is only half that size, should only have enough gravity to form rocky planets, not gas giants.

"Having worked for almost a decade to develop the NGTS telescope array, it's thrilling to see it picking out new and unexpected types of planets," said Prof Peter Wheatley of the University of Warwick, who is head of the NGTS project. The team's next challenge will be to watch and learn more about planetary systems like this one.

NGTS-1b is a 'hot Jupiter' orbiting a red dwarf star, which until now wasn't believed to be possible.



NEWS
Be gentle with those who are struggling. For things to get ahead, fellow humans, a study at Northwestern University says. Black and white research suggests that about dogs being beaten were more moved than those who were not.

THE BIRTH
A genetic mutation found in some members of an Amish community in Indiana, USA, can help them to live up to a decade longer than people without it, a study at Northwestern University has found.

GOOD MONTH

BAD MONTH

FAST EATERS

Talking your way into the dinner table is a harder task to a thinner, healthier you. A study led by the American Heart Association has found that slow eaters are significantly less likely to suffer from obesity, heart disease and stroke.

GRAMMAR PEDANTS

Researchers from the University of Pennsylvania have found that the English language is evolving by random chance, and is subject to the same drift found in natural selection in the animal kingdom.





MENTAL HEALTH

HALLUCINOGENIC DRUG BREWED BY AMAZONIANS COULD BE USED TO TREAT ALCOHOLISM AND DEPRESSION

A psychedelic drug traditionally used in South American shamanic ceremonies could be used to treat alcoholism and depression, new research from the University of Exeter and University College London suggests.

Previous studies have suggested that LSD and magic mushrooms can help alcoholics tackle their addiction, but now ayahuasca, a psychedelic brew often consumed in rituals in the Amazon region, has also shown promise.

The brew is made from a blend of the bush *Psychotria viridis* and the stems of the *Banisteriopsis caapi* vine. It is used in rituals by indigenous tribes and religious groups in the region, as well as being increasingly popular with visitors seeking psychedelic experiences. The resulting concoction contains dimethyltryptamine (DMT), a Class A prohibited drug in the UK.

IF YOU ARE WORRIED ABOUT YOUR ALCOHOL USE, CONTACT ALCOHOLICS ANONYMOUS ON 0800 977 7650. IF YOU ARE CONCERNED ABOUT YOUR MENTAL HEALTH, VISIT MIND.ORG.UK

Taking Global Drug Survey data from more than 96,000 people worldwide – including 527 ayahuasca users, 16,138 who used LSD or magic mushrooms and 78,236 non-drug users – the team found that ayahuasca users reported lower problematic alcohol use than people who took LSD or magic mushrooms, and higher general well-being than other respondents.

“These findings lend some support to the notion that ayahuasca could be a powerful tool in treating depression and alcohol use disorders,” said lead author Dr Will Lawn of University College London. “Recent research has shown ayahuasca’s potential as a psychiatric medicine, and our current study provides further evidence that it may be a promising treatment – though it is important to note that these data are purely observational and do not demonstrate causality.”

PHOTO: ALAMY/REXUS/ALAMY/REXUS

MYSTERIOUS ZOMBIE STAR KEEPS EXPLODING, BUT WON'T DIE

Morrissey was right – there is a light that never goes out. An international team of astronomers has made a bizarre discovery: a star that has exploded repeatedly, yet carries on shining.

When stars of a certain size reach the end of their lifecycle, they explode in energetic cosmic events known as supernovas. Such explosions have been recorded by astronomers thousands of times, and in every recorded case, such an explosion has marked the death of a star. But now scientists seem to have found an exception: in IPTF14h, a supernova that has exploded at least twice in the past 70 years.

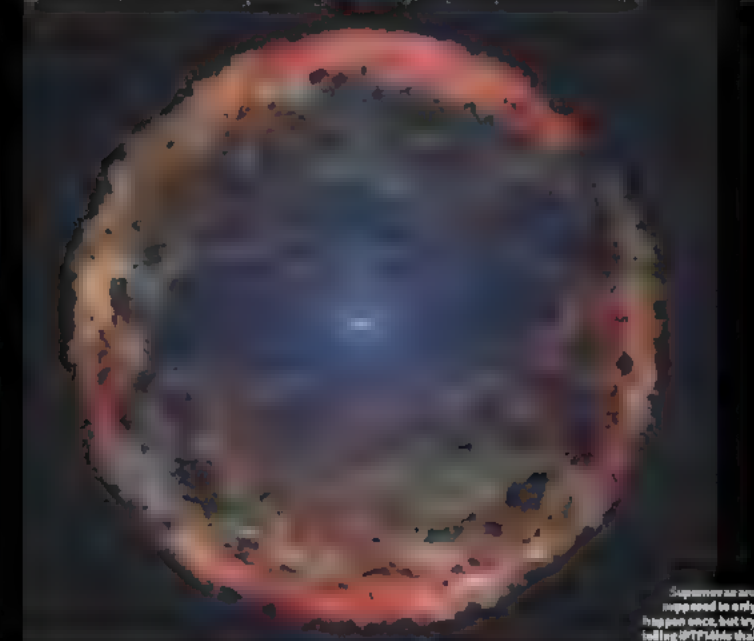
“This supernova breaks everything we thought we knew about how they work. It’s the biggest puzzle I’ve encountered in almost a decade of studying stellar explosions,” said Dr Iair Arcavi of Las Cumbres Observatory.

IPTF14h was discovered in 2014 by researchers at Caltech. At first it appeared

normal, but seven months after it faded it began growing in brightness. When astronomers went back and looked at archival data, they found evidence of an explosion in 1944 at the same location. The star has somehow survived the first explosion, only to explode again in 2014.

One potential explanation has to do with the star’s mass. Having at least 50 times the mass of our Sun, it could have been big enough to be the first example of a theorised event known as a Pulsational Pair Instability Supernova – a star so massive and hot that it created antimatter at its core, which in turn caused it to undergo repeated explosions.

“This is one of those head-smacker types of events,” said Dr Peter Nugent. “At first we thought it was completely normal and boring. Then it just kept staying bright, and not changing, for months after months. I would really like to find another one like this.”



Supernovas are supposed to only happen once, but by finding IPTF14h, that

THE DOWNLOAD

W Hydrae

What's this? The multi-headed serpent killed by Heracles?

Nope. It's a red giant star, located 320 light-years from Earth in the constellation of Hydra, that was recently observed in unprecedented detail by researchers at the ALMA Observatory in Chile.

What's special about it?

When it started life, W Hydrae had a very similar mass to the Sun, making it an ideal subject to study to learn more about the ultimate fate of our Solar System's own star.

Tell me more!

Stars like the Sun age over many billions of years. As they reach old age they swell up, becoming larger and cooler as they grow, and losing mass thanks to the action of solar winds. During this stage they release elements for the formation of new stars and even life – such as carbon and nitrogen, into space.

Currently, W Hydrae is around twice the size of the Earth's orbit around the Sun.

So what's next?

The team plan to take further, more accurate, images in order to study how the processes change as the star ages.

The teeth found in Devon came from two small, rat-like mammal species that co-existed with dinosaurs



PALAEOLOGY

TEETH SHED NEW LIGHT ON MAN'S EARLIEST ORIGINS

Two fossilised teeth found in Devon's Jurassic coast have been identified as belonging to some of man's earliest ancestors.

The teeth belonged to two previously unknown species of small, rat-like creature that lived around 145 million years ago, during the Early Cretaceous period. The two species, which have been named *Duristoeia* and *Duristoeia*, have been named *Duristoeia* and *Duristoeia* are now officially the earliest known creatures to be identified as not just to be a rat, but a pretty much all mammals that are a very tiny – from the tiny pigmy shrew to a giant blue whale.

The fossilised teeth were discovered by Grant Smith, an undergraduate student at the University of Exeter. After examining them, he realised that they were of some kind of early mammal and showed them to his supervisor, Prof Dave Martin, who, excited by the find, convinced Dr Steve Sweetman, an

expert in early mammals, who confirmed the specimens' remarkable age.

"Even at first glance my jaw dropped. The teeth are of a type highly evolved that I remember straight away I was looking at teeth that Early Cretaceous mammals that more closely resembled those that lived during the latest Cretaceous, some 60 million years later in geological history," said Dr Sweetman. "Our 14-million-year-old teeth are undoubtedly the earliest yet known from the line of mammals that led to our own species."

The creatures from which the teeth are thought to have been made – burrowing mammals and most likely nocturnal.

The teeth are very worn, which suggests the animals to which they belonged lived to a good age for their species, said Dr Sweetman. "No mean feat when you're sharing your habitat with predatory dinosaurs!"

THINGS WE LEARNED THIS MONTH

BLUE LIGHT CAN HELP TO RELAX US FOLLOWING AN ARGUMENT

If you find your blood boiling after a bit of argy-bargy, get yourself a blue light. A team at the University of Granada has found that blue lighting can help us to calm down.

DOGS ARE RED/GREEN COLOUR BLIND

Thinking about playing fetch with your dog in the park? You might want to think twice before buying a red ball: researchers at the University of Bari, Italy, have found that dogs can't distinguish between the colours red and green.

EATING MUSHROOMS COULD HELP US LIVE A LONGER, HEALTHIER LIFE

High levels of the antioxidants ergothioneine and glutathione found in mushrooms could help to prevent cell damage caused by free radicals – oxygen atoms with unpaired electrons produced when the body uses food to produce energy.

CATS COULD PREVENT CHILDREN GETTING ASTHMA

Danish researchers have found children who grow up in families that keep cats are far less likely to suffer from asthma. The effect is thought to be down to specific genetic triggers for the conditions being switched off when children are in regular contact with moggies.

PHOTO: GETTY IMAGES/UNIVERSITY OF PORTSMOUTH

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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

CHRISTMAS 2017

ED TEEB / RUSSELL DEERY



Reports show VR systems to be the graphics bar with 60 resolution

GAMECHANGERS

As the year draws to a close, we take a look back at the tech and gadgets that left a mark in 2017.

First up are two virtual reality headsets that highlight how rapidly VR is evolving. Consumer VR has so far mostly come in two flavours. Either you wear a costly headset connected to an even more expensive PC/Mac, or you tuck your phone into a visor, which is less immersive but a lot cheaper. But now there's the Oculus Go, a standalone dedicated VR headset and handheld controller that require no other hardware – giving you the best of both worlds for just \$199 (£159 approx).

Meanwhile, a new headset from Japanese start-up Pimax VR recently broke the Kickstarter funding record previously held by Oculus Rift. Their headset promises unparalleled immersion, with each eye treated to its own 4K display.

But while VR has been big news in 2017, it wasn't the only technology to be developing apace. So over the next eight pages, we look at some of the hottest topics in tech in 2017, from robots to AI to electric cars, and ask, 'Where next?' The future starts here.



1 Taking its design cues from hybrid portables, ZTE's latest smartphone features a hinged body and two 5.2-inch screens. You can have one screen mirror the other, multi-task in two different apps or combine the two into one large display.

ZTE Nubia X £349 (zte.com)

2 Sony's robot dog was an instant hit in 1999, and went on to sell over 150,000 units. And now it's back with improved robotic movement, enhanced 21st Century AI smarts, and a camera in its nose. It goes on sale in Japan from January.

Sony Aibo £1,000 (sony.co.uk)

3 This is the only TV that makes us a little weak at the knees. The OLED display means there's no need for backlighting, making it thinner, lighter and more visually accurate than most. Weighing in at 7.7kg the TV it can be mounted on magnets.

LG OLED65E9C £1,999 (lg.co.uk)

4 Nintendo made consoles fun again. The switch is a design masterpiece. Its portability means you can queue in game time wherever you are, and it's simple central system lets you get all your friends and family involved. We want one.

Nintendo Switch £349 (nintendo.co.uk)

5 Plug in these pods around your house to optimise your wi-fi network's bandwidth and manage Steam, Netflix in one room and YouTube in another, and the system will shuffle your data around the plugs to create capacity for both.

TP-Link Deco M5 £199 (tp-link.com)

6 Nuraphone's eponymous headphones feature both an in-ear bud and an over-ear cup, and are tuned to your hearing by means of some arcane wizardry called 'otoscopic profiling'. Focus editor Dan says they're among the best headphones he's ever heard.

Nuraphone £299 (nuraphone.com)

7 This is the first iPhone we've been excited about in a long time. There's not actually a lot of new tech here, but it's the way it's been put together. The edge-to-edge OLED display, True Depth Camera and slick interface make it feel like the phone of the future.

Apple iPhone X £799 (apple.com)

8 The earphone to rule all earphones, these in-ears feature ultra-thin drivers, a magnetism body and a silver-coated copper cable braided in Kevlar. They sound like nothing else – just don't drop them in the washing machine.

Beats Solo3 £129 (beats.com)

9 Sky's Soundbar makes mini drivers that bounce sound off nearby walls to create a 3D soundstage. There are also some really HQ options such as Q Sound which adjusts the sound output based on metadata in the TV stream.

Sky Soundbar £199 (sky.com)

10 The compact and bijou Spark may be one of DJI's tiniest drones in data, but it packs the same AI obstacle avoidance and gesture control as its bigger brothers – and it's a tad more affordable. The drone is officially here.

DJI Spark £149 (dji.com)

11 At time of writing, this Lego set paying tribute to female pioneers of space exploration was the No 1 best-selling toy on Amazon. The set includes four minifigures, plus tiny versions of the space shuttle and the Hubble Space Telescope.

Lego Technic Space Explorer £49.99 (lego.com)

12 The iPhone X grabbed the headlines, but Samsung's latest Galaxy phone offers very similar specs for a whopping £300 less. With Google's Pixel 2 phone also just landed, the high-end smartphone market remains highly competitive.

Samsung Galaxy S8 £649 (samsung.co.uk)

TRANSPORT

PETROL AND DIESEL CARS GET AN EVICTION DATE



Dirty air is making us ill. In fact, 48,000 premature deaths per year can be attributed to poor air quality according to the Royal College of Physicians. So news in July that the government was going to clean up our air was welcome. The headline was that the sale of petrol and diesel cars and vans would be banned by 2040 – with hybrids being exempt. But the initiative was greeted by a healthy dose of skepticism. Firstly, climate and environmental experts felt the deadline wasn't soon enough: we'll still be breathing in pollutants for the next 22 years. Secondly, the government didn't explain how the country might prepare for a new influx of cars needing somewhere to plug in. To cope with the extra energy demand, it's estimated we'll need 30GW of extra electricity per year, equivalent to the output of 10 more Hinkley nuclear power stations or 10,000 more wind turbines. Finally, the RAC pointed

out that it wasn't clear what the ban meant for drivers, with big cities likely to start imposing their own restrictions on polluting vehicles much sooner. There's also a fear of pessimism, though. While the infrastructure strategy is lacking, car makers from Nissan to Volvo to Jaguar are competing to make themselves in an emissions-free age. Nissan, which produced the Leaf – the first proper electric car – said it to compete in the Mongol Rally, proving that you don't need fossil fuels to go longhaul. It also unveiled home charging stations which can store power from the grid at off-peak hours, to lower costs. Dyson announced plans to build an electric car in the near future while Tesla recently answered the question "What about trucks?" with its Electric Semi, which can haul 36 tonnes for 500 miles on a single charge.

Car makers are competing to reimagine themselves in an emissions-free age

Plug-in Adventures' Nissan Leaf is the first vehicle to complete the 13,875km Mongol Rally

SMART HOMES

ALEXA USHERS IN THE INTERNET OF THINGS

Focus's year in tech started at the CES show in Las Vegas, where Amazon's voice assistant Alexa could be found in over 30 products. That trend continued all year, with new Alexa devices hitting the shelves almost daily, and Amazon itself recently unveiling a raft of new Alexa products including Echo Spot, Echo Connect and, most significantly, Echo Plus, which doubles as a fully-fledged smart home hub. With Alexa now in so many homes, this is an obvious next step. When tech companies first started talking about 'internet fridges' and other Internet of Things (IoT) devices, people laughed: who needed to go online or fumble about in an app to see if they had milk, when they could just open the fridge door? But introduce Alexa to the mix, and suddenly you can check if you've got milk, and order more if you haven't, without even reaching for your phone. So expect 2018 to be the year when the IoT – Now With Voice Control™ – finally takes off. But at what price? Almost as frequent as Alexa product launches

in 2017 were alerts about security weaknesses in IoT devices – from the Amazon Echo, to Nest security cameras, to children's toys and smartwatches aimed at kids, which Germany has just gone so far as to ban outright. In May, Daniel Coats, the US Director of National Intelligence, suggested insecure IoT devices could be used to launch cyberattacks on vital infrastructure, while a recent report by German security specialists Gemalto found that just 52 per cent of data captured by such devices is encrypted. John Moore, managing director of the IoT Security Foundation, told Focus: "At this point in time there are no specific regulations for IoT security, and this explains in part why we are seeing so many problems. But we're starting to sense a consensus form around the key requirements for IoT security and we are encouraging governments considering regulation to look hard at our expert-led work, so as to translate this into useful regulation for responsible suppliers, consumers and citizens."

Alexa is everywhere – most recently in (clockwise) the Amazon Echo Plus, Echo, Echo Connect and Echo Spot



ARTIFICIAL INTELLIGENCE

AI BEATS PUNY HUMANS

As Elon Musk and Stephen Hawking issue stark warnings about the singularity, Garry Kasparov says we should stop worrying and learn to love the all-knowing machine brain

PHOTO: DEEP DREAM GENERATOR

If Artificial Intelligence (AI) were truly smart, it would force good PR for a start, we would not see a surge of AIs, which complicates our every conversation about what effect it will have on our lives. We can't even really agree on what will generate AI, let alone where the conversation inevitably overflows from science and into philosophy.

As a rather successful philosopher, but with decades of personal experience on the front lines of tech, I am not an AI evangelist or I prefer to focus on the practice. AI will be the greatest technological advance since the internet, turned the world into a living stream of data. It will be more subtle than all the social media and eventually more transformative on the web, changing every part of our lives in seen and unseen ways. AI is already happening.

After many recent conversations with AI futurists such as Dennis Hasselbus of Google's DeepMind in London and legendary technologist Ray Kurzweil, also now at Google, I came to the conclusion that I find it as important to remain aware of my weaknesses as that of Artificial Intelligence in its own. It is a big, inevitable wave of better things going through products of AI, the driverless cars, the smart phone assistants and, for better or worse, the chess-playing machines. Meanwhile, there are countless others that are getting a little smarter each day and millions of others that are improving themselves with machine learning processes.

Practical AI, diagnosis, investment banking, forecasting, staff scheduling, research ideas, these increasing capable systems are helping the world. These intelligent agents are the only way to sift through the oceans of data we are

processing at an exponential rate, revealing the deeper patterns and insights into how the world, our bodies and our minds work.

Whether you find this terrifying or wonderful is important, because public sentiment drives a lot of our investment and regulation, making the outcome a type of self-fulfilling prophecy. That's why I don't find the rapid advance of intelligent machines terrifying, instead of

"I'm glad that great minds like Stephen Hawking and Elon Musk are voicing their concerns"

wonderful, it won't stop, but I don't want to make it any much worse. Powerful, new technologies disrupt and nearly always cause a stress before producing broad benefits. By slowing down our progress out of unreasonable fear, we're prolonging the stress phase by weaving the next waves through it, which needed to produce better things for benefit.

There are real and imminent concerns about the proliferation of intelligent machines, especially autonomous ones. Rising inequality if automation hits lower income people harder, transparency and accountability of the

Former chess grandmaster Garry Kasparov was famously beaten by an AI system, but now he's a firm advocate of the technology

algorithms, personal data being hoarded and abused by private companies or repressed by regimes. None of these issues are nearly as close to a rock-bottom threat—the killer robots of Hollywood or the super intelligent AI that sees no reason to keep humans around. It was of no use of worrying about it with spreading the thought, new wave of the modern world, a century ago, even in a world obsessed about how we might all one day be obsolete.

As a member of the executive board of the Foundation for Responsible Robotics and as a senior vice president for Avast Software, I've been on the front lines with the real threats. AI is not a threat, machines may pose. And I agree that great minds like Stephen Hawking and Elon Musk are voicing their concerns, and that of AI enthusiasts like Nick Bostrom, are mapping out the worst case scenarios. After all, we've got nuclear power that could literally destroy the planet. I do, I certainly want it to be monitored and used responsibly.

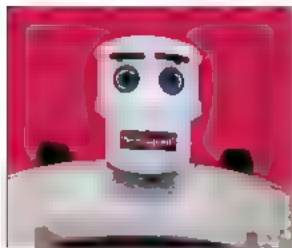
But like all our inventions, AI is agnostic, capable of being used for good or evil. Morality matters and so making better humans was always become important than making smarter machines. Ahead of, we must keep moving forward, because the only solution for the problems caused by today's technology is tomorrow's.

For more news, join Garry Kasparov on the Deep Thinking Where Machines and Humans Creatively Engage
[http://www.garrykasparov.com/deep-thinking](#)

BUCKERING BOTS

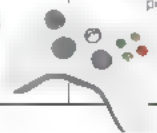
ROBOT VICAR

In May, a church in Wittenberg, Germany took delivery of a vaguely humanoid robot called Bless-u-2. When you pressed a touchscreen on the robot's chest, its arms raised up and its computerized mouth offered up a blessing in German, English, Polish, Spanish, French. Sadly though, it was only in the church for a short time, as it was an exhibition marking the 500th anniversary of the Reformation.



SONIC ATTACK

The weirdest tech story of the year so far involved the K. family of his. Since August 2011, and he families have reported hearing strange piercing noises that caused them problems afterwards with memory hearing and speech. Various theories have been put forward - from a mysterious sonic weapon to mass hysteria - but a concrete explanation has yet to emerge.



FAR OUT

Ever fancied becoming a citizen of space? In June, while we're up at 220 miles and has over 100 million

space in association with commercial satellite providers like SpaceX.

June 6, 2018

SUBMISSION

In September the U.S. Navy announced it was scrapping the E-70K joystick Lockheed Martin designed for the new Virginia-class submarine. Instead, they'll use the Xbox controller. They do the job just as well, need no special training and you can

pick up a spare
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PEAK DATA

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kill? Or five hours?
surprise hit browser
game it is As if you Were
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190s Wink
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FLYING SQUAD

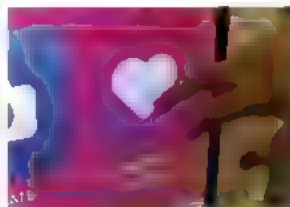
Working 24 hours a day, among other duties, AAs are asked to search for and identify victims of traffic accidents.

ROBOT NIRVANA

[illegible]

FAKE FANS FOR SALE

in July outraged reports started

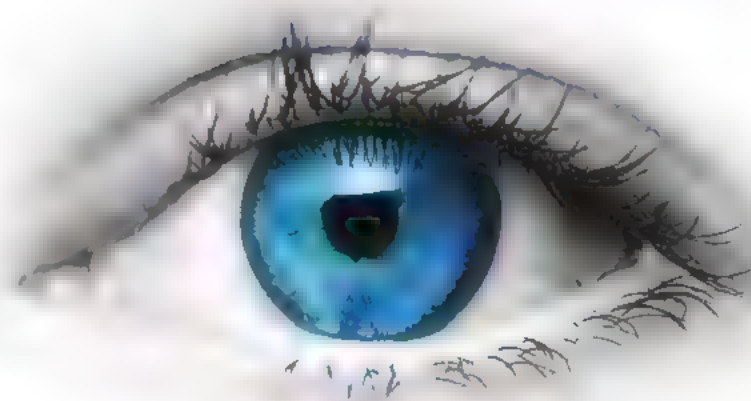


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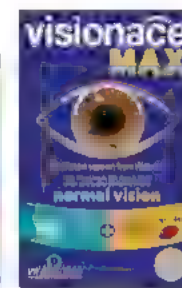
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UNLOCKING THE SECRETS OF THE BRAIN

From autism and schizophrenia to Alzheimer's, lab-grown mini-brains could be the key to solving the biggest mysteries about human development and disease

WORDS: SIMON CHAMPTON

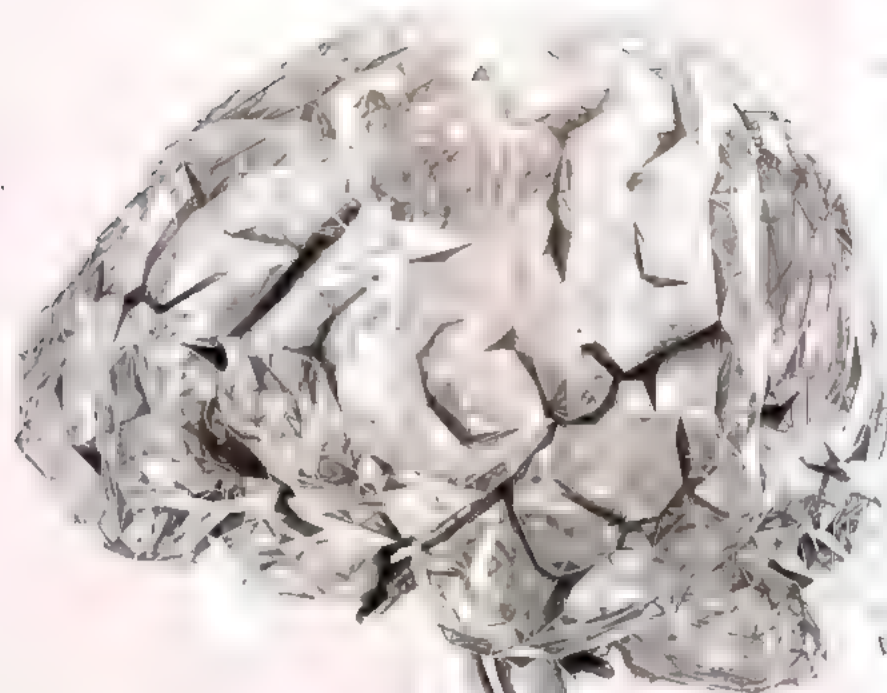


ILLUSTRATION: MARK TOLIC

S

tacks of little plastic dishes in a laboratory incubator, each one holding a free-floating blob of human brain might sound like the stuff of science fiction. But this is no futuristic fad of the imagination. These strange

creations, known as brain organoids, are already being cultivated in labs all over the world, and research here believes they could unlock some of the deepest secrets of how our brains grow and what happens when they go wrong.

"I don't think half any of us set out to try and grow a brain in a dish," says Madeline Lancaster, a neurobiologist at the MRC Laboratory of Molecular Biology in Cambridge. "If you'd asked me even just a few months before I started working here, I would have said it was completely nuts – but in my case, it was an accident."

Lancaster's accidental experiments with organoids started when she was a postdoctoral researcher, first working in Vienna with molecular biologist Jürgen Knoblich. Investigating how the brain forms during development in the worm. She started by growing brain stem cells in two layers in a dish, but soon realised they lacked many of the key characteristics of nerve cells in a real brain. In search of a better method, she tried a new technique for growing neurospheres – flat, flower-like circles of cells that were more realistic, albeit still two-dimensional.

When I put the cells in the culture dish, there was something wrong with the organoids that I was seeing, she says. "Rather than forming these neurospheres, mine were forming these weird, floating balls. I thought they looked interesting, so I continued growing them."

Speaking to other researchers in the field, she discovered that some of them had also seen these strange blobs, but had thrown them away because they looked wrong. But while these brain balls looked curious from the outside, what Lancaster found inside was fascinating. Each was made from billions of cells, organised in a way that looked like the fluid-filled

A bright-field microscopic image of a cerebral organoid, revealing this mini brain in 3D across

ventricles that connect the hemispheres of the cerebral cortex in a real brain. Even the layers of cells mimicked the arrangement in natural brain tissue, with the ventricles at the core and layers upon layers of more specialised cells and neurons built up towards the outside.

BUILDING A BRAIN

Despite their 'mini-brain' nickname, these organoids are a long way from being full-size human organs. They're around half a centimetre in diameter, roughly the shape and size of those at the end of a pencil – and they lack key structures such as blood

One of Madeline Lancaster's cerebral organoids, seen here in cross-section

vessels, which are how they

have to grow.

Organoids are also remarkably easy to keep as long as they take root in a scrupulously clean environment and can stay alive for more than a year. Lancaster's mini-brains are enabling her to prise open the 'black box' of human brain development. Because they reflect the cell types and organisation of a growing human brain, organoids are opening a window into one of life that has previously been inaccessible.

People have done MRI scans on embryos and even babies to look how the brain works, but when it comes to those early events – how neurons are made, how many, which types, and when – we can't answer them, no matter how good our MRI machine is. But I think what's happening in these

dishes reflects what's happening in an actual embryo. We know this because the

end product looks a lot like a real brain, so we have a tractable system to start asking some of those fundamental questions about brain development.

Lancaster is also using her mini-brains to answer an even deeper question: what makes a human brain human? We share more than 95 percent of our DNA with our closest primate relatives, such as chimpanzees, but our brains are much bigger and more intelligent. By comparing brain organoids grown from chimp stem cells with those from humans, she and her team are watching how these differences emerge from the earliest stages of development. There's even the possibility of using new genetic engineering techniques to switch human and chimp genes around in mini-brains – something that would be impossible to do in living animals – to pin down the precise molecular pathways that make the human brain so special.

Cambridge neurobiologist Madeline Lancaster was the first person to start growing mini-brains

The process of building a mini-brain starts with a genetically modified human skin cell

PHOTOS: MRC LAB; SCIENCE PHOTO LIBRARY

"Despite their 'mini-brain' nickname, these organoids are a long way from being full-size human organs"

• The brain-like appearance of these organoids raises ethical as well as scientific questions. Can they think, and are they conscious? According to Lancaster, the answer is almost certainly no.

"I think of them as being a bit like brain tumours," she says. "Tumours contain many more neurons than our mini-brains in a dish – but no one is concerned that their brain tumour is thinking or has consciousness, and nobody is sad that it has been taken out and thrown away. That's what we have here. It's not an organised network, and it cannot make a function, thinking circuit – it's a ball of brain tissue, and just because you have neurons doesn't mean it can think."

Today, she and her team are growing mini-brains from human embryonic stem cell lines – the multipurpose cells originally found in very early human embryos, but now cultivated in the lab. She is also using so-called induced pluripotent stem (iPS) cells: adult cells that have been pushed back to an embryonic state with a cocktail of molecules first discovered by Nobel Prize-winning Japanese scientist Shinya Yamanaka. Depending on the exact conditions used, Lancaster can nudge her organoids to develop all kinds of cells – from the fluffy choroid plexus (which would connect with blood vessels in a real brain) to pigmented light-sensing cells that are usually found in the retina at the back of the eye.

"There's just so many cell types to look for," she says, "But depending on the method we use, every time we look for something that we know should be there, we find it."

WIND UP

Mini-brains don't just allow researchers to study normal developmental processes. Sergiu Pasca, Assistant Professor of Psychiatry and Behavioral Sciences at Stanford University in California, is using them to understand what goes wrong in autism, schizophrenia, epilepsy and other neuropsychiatric disorders.

"Most of the psychiatric drugs we have today have been discovered by chance – we know very little about the origins of these disorders and the question

is why?," he asks. "Unlike cancer biologists, who can take out a tumour, put it in a dish and find ways to treat it, we cannot do that with the brains of our patients with mental disorders."

Pasca and his team have managed to grow mini-brains for more than two years – a staggering 800 days is their current record – and shown that they can generate most of the same cell types and structures found in real human brains. They're using the technique to investigate the roots of severe autism and epilepsy syndromes, by generating organoids with iPS cells derived from skin samples of affected children and then carefully comparing them with cultures grown from healthy cells.

"We can use electrodes to measure how the cells are talking to each other, and time-lapse microscopy to see how the cells move and make connections with each other," he explains. "Many of the genes associated with these disorders are involved in the connections between neurons, so we can see how the gene changes in these patients are impacting the communication within the brain in a comprehensive way."

He is now taking these ideas even further: sticking together organoids that mimic different regions of the brain and studying their interactions – a technique he describes as "brain Lego". The team is using these hybrids to spy on the brain as it wires itself up, focusing on what happens to so-called inhibitory neurons that normally help to calm down brain activity but are faulty in people with epilepsy and autism.

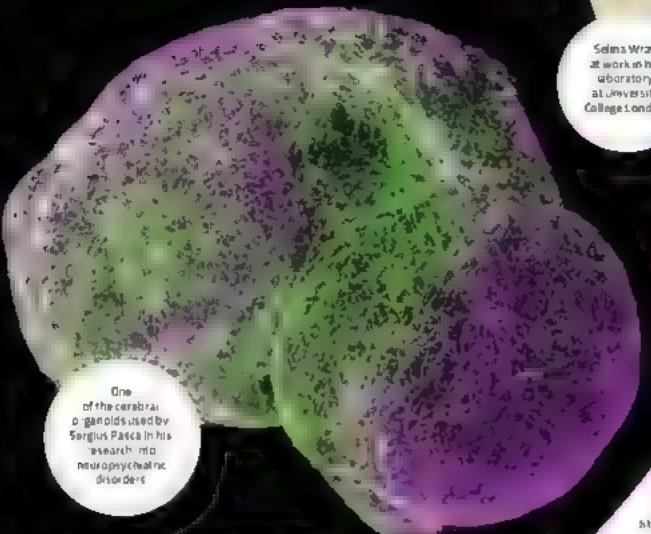
"Inhibitory neurons are not born in the cortex on the surface of the brain – they are born in a very deep region of the forebrain and have to migrate millimetres over many months after birth," Pasca says. "It's really fascinating to watch in our cultures – they kind of pull themselves up and jump along."

But when Pasca and his colleagues looked at organoids grown using cells from patients with a

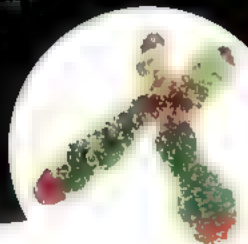
"Pasca and his team have managed to grow mini-brains for more than two years – a staggering 800 days is their current record"

Sergiu Pasca, holding 'mini-brains' used to study the development of conditions such as autism

PHOTO: JAY CLAY



One of the cerebral organoids used by Sergius Paeta in his research into neuropsychiatric disorders



An X chromosome: the red areas at the end of the arms are telomeres, which play a role in ageing

Selma Wray at work in her laboratory at University College London



● form of autism that is associated with epilepsy. They saw a very different picture. The inhibitory cells were firing in a very peculiar way – jumping more often but less efficiently and eventually getting off behind. Impressively, the researchers were then able to identify a drug that could reset these ageing cells, correcting the wiring defect and pointing towards a potential future treatment for children suffering from the same condition.

INTUITION

Meanwhile at University College London neurologist Selma Wray is using brain organoids to look at neurodegenerative conditions that start at the other end of life, including Alzheimer's disease and fronto-temporal dementia.

Normally we have to wait with post-mortem brain tissue from patients, but you're only ever looking at the end stages," she says. "It's almost like

coming to the scene of a crime after the criminal's gone, and you're trying to piece together a sequence of events by looking at the damage that's been left. I want to be a detective in the lab which is why I let us look at the very beginning of the disease – because if we understand the first things to go wrong, that's when treatment should be more effective.

In a similar way to Pasca and Lancaster, she's taking samples of skin from patients with dementia, turning them into iPSCs and then growing organoids. Wray can spot differences compared with organoids from unaffected people after just a few months, finding increased levels of the forms of certain molecules that are associated with Alzheimer's disease.

However, there's a problem with this approach: mini-brains mimic the very earliest stages of life, while dementia is a problem that takes decades to develop. To solve this, researchers are working on clever hacks to speed up the ageing process. One hack is to add genetic changes that turn on premature ageing. Another approach is to meddle with the structures protecting the ends of DNA inside cells, known as telomeres, which act as a kind of clock on a check as we age.

As well as studying the underlying processes that drive dementia, Wray thinks that mini-brains have a great potential for helping to identify the right treatment for individual patients.

I feel excited by the idea of personalised medicine – that you could take somebody's cells and grow organoids in the lab, screen a panel of

"Mini-brains mimic the very earliest stages of life, while dementia is a problem that takes decades to develop"

drugs against them and say, 'Okay, we think this person will respond better to drugs ABC, but this person will respond better to drugs XYZ,'" she says. "That's happening in cancer biology, this idea of being able to stratify patients on a molecular basis, and while I think we are a long way off, I love the idea of growing someone's neurons so we can work out what therapies we should be giving them."

Sergiu Paeta is similarly enthusiastic about the potential of mini-brains to change lives.

"Our organoids are grown from cells taken from newborns," he says. "These kids have severe neurodevelopmental disorders that really impair their lives, and to think that a few months after you can derive brain tissue from those patients in a dish and start asking questions about how the disease may arise – that's what makes this exciting."

Kat Arney
How To Code Ageing: Between Cells And A Dish

ALL THE ORGANOIDS

It's not just brains: researchers are creating three-dimensional organoids from many different types of tissue, not only to study healthy development but also to discover what happens when things go wrong and to develop future therapies. Here are some of the types they've managed to grow so far.



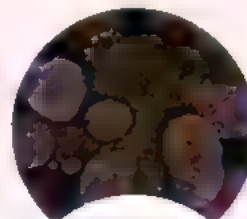
GUT

Scientists have made organoid versions of many parts of the gastro-intestinal tract, from taste buds to the intestines and stomach. Intestinal organoids can be manipulated to produce insulin, suggesting possible future treatments for diabetes.



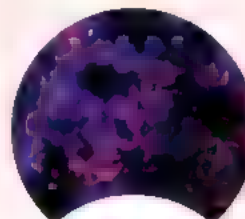
LUNG

Although they're a long way from a 'lung in the lab', lung organoids grown using reprogrammed stem cells from patients with diseases such as chronic asthma and cystic fibrosis could be useful models for finding new treatments.



BREAST

Mammary organoids grow the same branching structures that are seen in human milk ducts. Because many breast cancers start from such ducts, these organoids are providing vital insights into tumour growth.



THYMUS

The thymus gland is the place where infection-fighting immune T-cells mature. Thymus organoids can produce functional human T-cells, which could potentially be used to restore the immune system in transplant patients.



HEART

Cardiac organoids are revealing hidden regenerative pathways that could be reactivated to treat heart disease. Researchers also created organoids with functional, beating chambers, as a model for studying heart failure.

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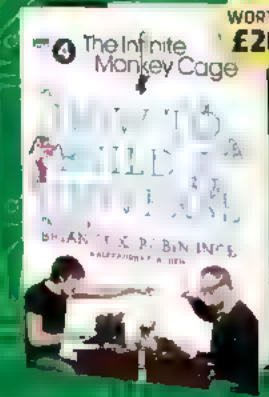
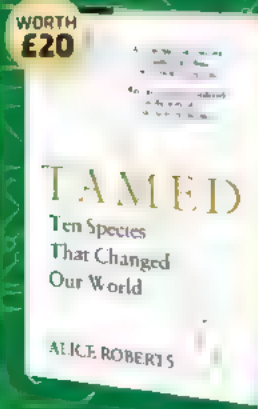
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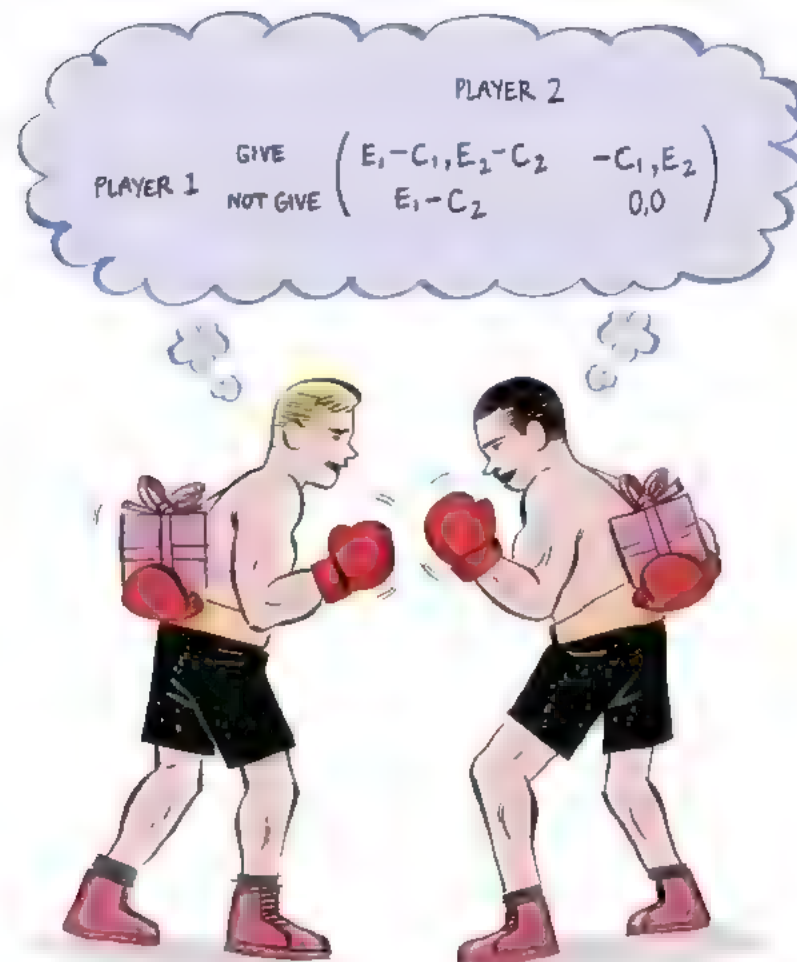
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SCIENCE HACKS FOR A PERFECT CHRISTMAS

Use the power of science to make 2017 the best Christmas ever

WORDS PAUL PARSONS



HOW TO GO CHRISTMAS SHOPPING

You have a long list of family and friends, but only limited funds in the bank. Who should you buy presents for?

Prof Rachel Norman and Dr Anthony O'Hare, at the University of Stirling, have applied game theory to the exchange of gifts. Game theory is a branch of maths to do with calculating optimal strategies in competitive situations. Central to it is the idea of finding the unexploitable 'Nash equilibrium' if two people are both playing the Nash strategy then neither can improve their lot by changing tack.

Let's say receiving a present involves enjoyment, E , but giving incurs cost, C . The diagram above shows the possible payoffs for two people. For example, if player 1 gives but

player 2 doesn't then player 1 gets $-C_1$ (a net cost) while player 2 has no cost but gets enjoyment E_2 .

The Nash equilibrium here is for both players to not give. The payoff for each is then zero – and if either one deviates unilaterally they become worse off.

This assumes that the 'game' is only played once. American political scientist Robert Axelrod has shown that when games are played many times, greedy strategies like this are no longer optimal. Instead, the best payoff comes from a 'tit-for-tat' approach – buying a present on the first Christmas and then, in subsequent years, copying what the other person did last time.

ILLUSTRATION: JAMIE COX

HOW TO CUT A CHRISTMAS CAKE

If you're tired of forcing down dried-up Christmas cake in March, then the good news is science has found a simple way to keep cake fresher for longer.

In a letter to the research journal *Nature*, published on 20 December 1906, the great British polymath Sir Francis Galton opined that the traditional way of cutting a Christmas cake was "very faulty". He argued that taking a wedge out at a time leaves the inside surface of the cake exposed and liable to get dry. Instead, Galton advocated a novel method of cake slicing that involves making parallel cuts through the centre of the cake and then closing it up and

securing with an elastic band to lock in the freshness.

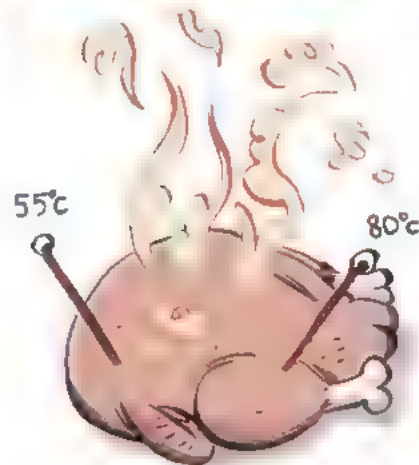
This is shown in the diagram adapted from a sketch that accompanied Galton's original letter. Solid lines show existing cuts, dotted lines show the next cut to make. The first cut, shown on the left, removes a flat slice and the cake is then closed up into an oval shape and stored. The next slice is removed in a similar fashion but at 90 degrees to the first cut, as shown in the centre image. The next slice would be taken parallel to the first cut and so on.

"The method works," says maths writer Alex Bellos. "I have done it many times."



$$t = 1.13 \times W^{0.75}$$

$$\text{TEMP} = 165^{\circ}\text{C}$$



HOW TO COOK THE TURKEY

What makes the perfect Christmas turkey?

Roasting a turkey is tricky because the meat is made up of different components that have different cooking requirements. For example, the breast meat shouldn't be heated much above 60°C to prevent the cooking becoming tough, whereas the darker leg meat needs to reach at least 80°C and the skin requires as much as 200°C to trigger the Maillard reactions that brown the outside and create the characteristic flavour.

Prof Peter Berham, a gastronomically inclined physicist at the University of Bristol, says the ideal strategy is to chop up the turkey and cook each part separately at its optimum temperature. In case a heap of sliced turkey flesh isn't quite the table centrepiece you were hoping for, he suggests cladding the more sensitive parts in foil for the bulk of the roasting time.

But how long should that time be? The late Stanford University physicist Wolfgang Panofsky used the laws of heat conduction to come up with the formula $t = 1.13 \times W^{0.75}$, where t is the cooking time in hours and W is the weight of the turkey in kilograms. He assumed an oven temperature of 165°C (325°F) – and a spherical turkey.

For safety, it's recommended to use a meat thermometer and ensure the inside of the bird is cooked to at least 75°C. Bon appétit!

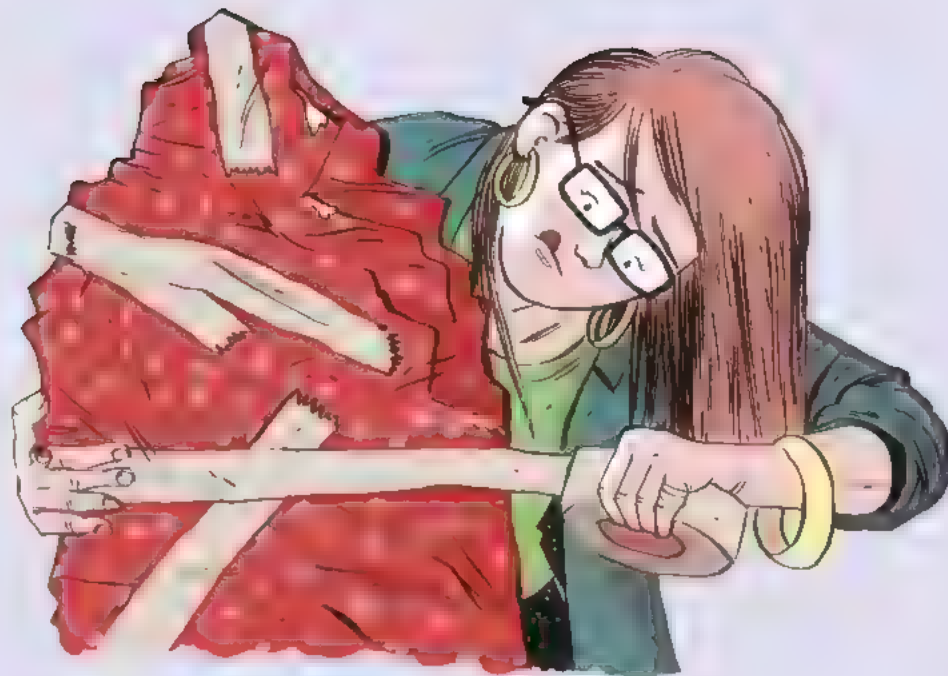


fig 1

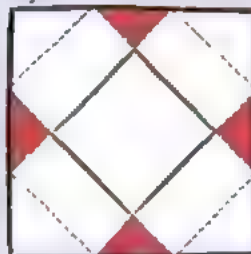
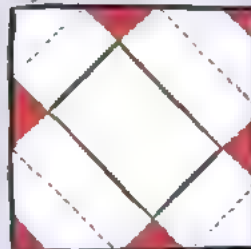


fig 2



HOW TO WRAP YOUR PRESENTS

Dr Sarah Santos of Goldsmiths

University of London has devised a formula to calculate the optimum dimensions of wrapping paper to cover a cuboid box.

For a square-based box, you need a square of paper with side length equal to the base diagonal of the box plus 1.5 times its height. Place the box on the paper at 45 degrees, bring the corners of the paper up to meet at the top of the box and secure with a single piece of tape (fig 1). For a rectangular base, use a square of paper with side length equal to the width of the box plus its length plus twice its height, all multiplied by 0.75 (fig 2).

That said, Erik Hannaford and

Thomas Oberwiesing in the book *The Independent Existence of Santa Claus*, argue that this technique uses no less paper than the traditional method – though it does look nice, and saves tape. They suggest a more practical approach is to use flatter boxes to minimise the paper wasted in flaps tucked in at the ends of the present. A box half as high as its base side length takes 11 per cent less paper than a cube of the same volume.

Taken to the limit, this means you should give totally flat presents – another reason to treat your nearest and dearest to copies of *Focus*.

HOW TO RUN A SECRET SANTA

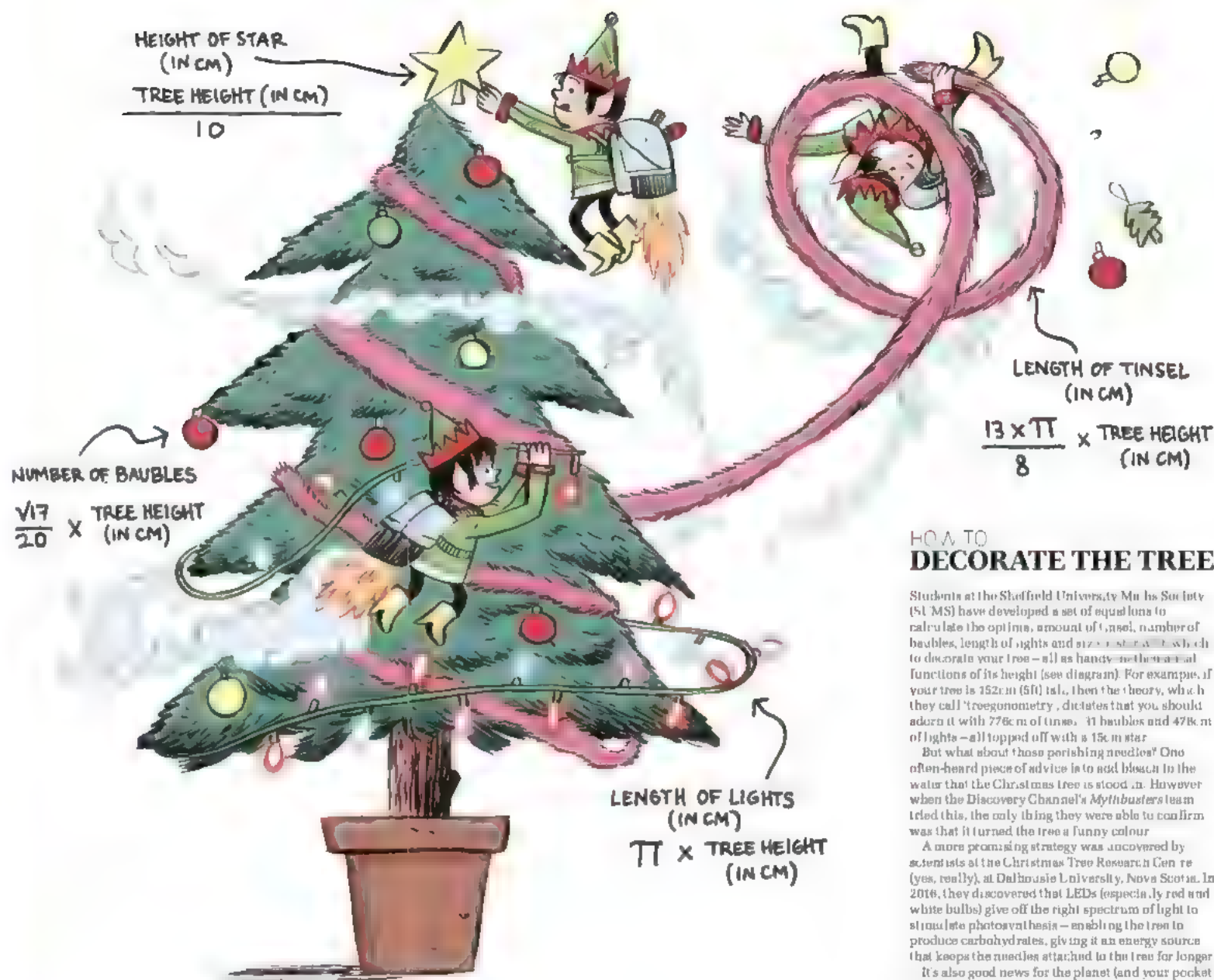
In the office game of Secret Santa, people write their names on pieces of paper, put them in a hat and then each draw one random person to buy a gift for. If anyone gets their own name, they replace it and draw again.

But this breaks down if the last person to draw picks their own name – in this case, to maintain anonymity, the only thing you can do is start over. And in an office of 10 people, this happens over 75 per cent of the time. It's also not perfect – random.

"If you're last to pick in a group of three, then it's twice as likely that the first picker is buying you a present than the second

picker," says Dr Hannah Fry. But she has a solution. Create a set of cards, one for each person. Each card should resemble fig 1. Place the cards face down in a row, shuffle and, keeping them face down, cut them in half. Now shift the cards on top one place to the right (fig 2).

Each person takes a card from the top row and the card directly below it – telling them their number and the number of the person they're buying for (fig 3). Finally, you put a list of numbers on the wall and everyone writes the name next to their number. Such a draw is fully anonymous and perfectly random.



HOW TO DECORATE THE TREE

Students at the Sheffield University Maths Society (SU MS) have developed a set of equations to calculate the optimal amount of tinsel, number of baubles, length of lights and size of star which to decorate your tree – all as handy mathematical functions of its height (see diagram). For example, if your tree is 152cm (5ft) tall, then the theory, which they call 'treegonometry', dictates that you should adorn it with 276cm of tinsel, 31 baubles and 478m of lights – all topped off with a 15cm star.

But what about those perishing needles? One often-heard piece of advice is to add bleach to the water that the Christmas tree is stood in. However when the Discovery Channel's *Mythbusters* team tried this, the only thing they were able to confirm was that it turned the tree a funny colour.

A more promising strategy was uncovered by scientists at the Christmas Tree Research Centre (yes, really), at Dalhousie University, Nova Scotia. In 2016, they discovered that LEDs (especially red and white bulbs) give off the right spectrum of light to stimulate photosynthesis – enabling the tree to produce carbohydrates, giving it an energy source that keeps the needles attached to the tree for longer.

It's also good news for the planet (and your pocket) as LED lights use 80 to 90 per cent less electricity than traditional filament bulbs. For more tips on keeping your tree looking spruce (sorry), see p98.

fig1.

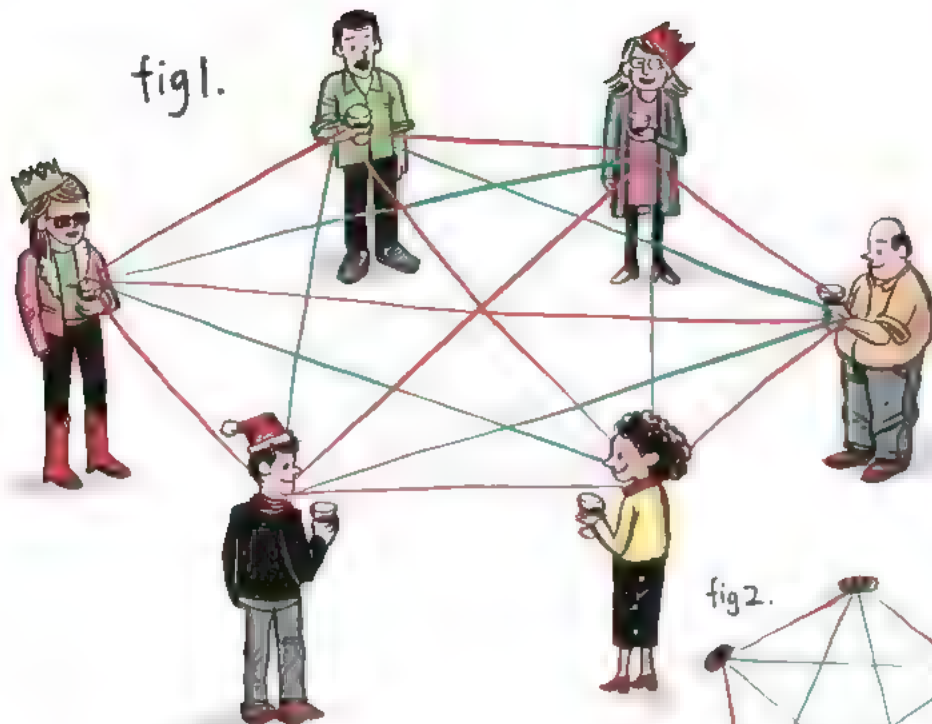
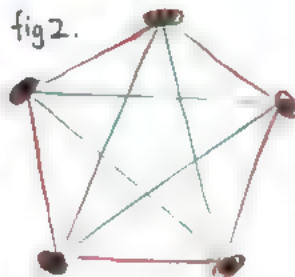


fig2.



HOW TO THROW A XMAS PARTY

So you're having people over at Christmas – how many do you want to invite? Do you want to invite everyone you want either to be a guest or to be a guest who are mutual strangers, or three or more who are already acquainted. So what's the minimum number of people to invite such that at least either m of them know each other, or n of them don't. It turns out that $R(3, 3) = 6$.

To see why, draw six dots in a sheet of paper each representing a guest. Now draw lines from each guest to every other guest – red if they know each other, blue if they don't. With six guests, you'll find it's impossible to connect them all without creating either a red triangle (ie, three people who know each other) or a blue triangle (three people who are strangers). But this isn't the case with just five dots (fig 2) – so six is the minimum number of people to invite.

Some more Ramsey numbers are shown in the table to the right. Notice that these are also symmetric, so $R(m, n) = R(n, m)$.

m	n	R(m,n)
3	3	6
3	4	9
3	5	14
3	6	18
3	7	23
3	8	28
3	9	36
4	4	18
4	5	25

HOW TO PACE YOUR DRINKING

Ever overdone it with the sherry on Christmas Eve?

In 1932 Swedish chemist Erik Widmark studied how ethanol (the pure alcohol in your plonk) interacts with the human body, and used his findings to devise an equation for a drinker's blood alcohol concentration (BAC). The BAC can be used to infer state of drunkenness, allowing the mathematical imbiber to plan their consumption accordingly.

The basic formula is shown in fig1. G is the amount of alcohol consumed (in grams), t is the time since drinking began (in hours), W is the drinker's weight (in kilograms), r is the gender constant (0.68 for men, 0.55 for women), and β is the rate that alcohol is eliminated from the body (in %BAC per hour, ranging from 0.01 for people with low tolerance up to 0.035 for seasoned boozers). Grams of alcohol is given by the 'alcohol by volume' (ABV) percentage of your beverage times the amount consumed in millilitres times the density of ethanol ($\approx 0.789\text{g/ml}$).

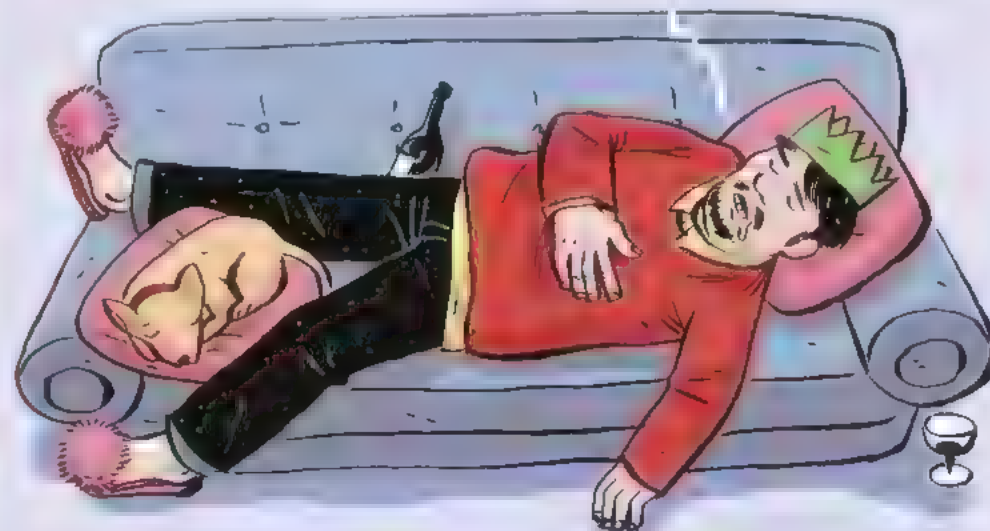
You can then look up the resulting BAC on the effects table to the right. For example, a man drinks five pints (2840ml) of 5% beer – that's 112g of ethanol ($2840 \times 0.05 \times 0.789$). If he weighs 90kg and has a moderate alcohol tolerance ($\beta = 0.02$) then his BAC after two hours is 0.143. Which is enough to cause a significant risk of missing Christmas dinner.

fig1.

$$\% \text{ BAC} = \frac{G}{10 \times W \times r} - \beta \times t$$

$$G = \text{ABV} \% \times \text{Volume} \times 0.789$$

BAC	Effects
0.01-0.039	Minor euphoria, relaxation, no visible effects
0.04-0.059	Euphoria, reduced inhibitions, slight impairment of higher brain functions
0.06-0.099	Balance, speech, vision and reasoning all impaired, memory, concentration and reasoning all impaired
0.1-0.15	Slurred speech, lack of balance, reaction times significantly impaired
0.16-0.199	Vision blurred, difficulty walking straight, possibility of amnesia, severe impairment of senses and higher reasoning
0.2-0.249	Complete loss of coordination, anxiety, possibility of nausea, confusion, disorientation, needs help to stand, vomiting likely, possibility of passing out
0.25-0.299	All body functions severely impaired
0.3-0.349	Complete stupor, loss of awareness, passing out likely
0.35-0.399	Risk of coma and death
0.4-	Coma and significant risk of death



Dr Paul Parsons is a science writer and an analyst with the bookmaker BetVictor. He tweets from @NasaProPlus



CAN MATHS DEFEAT TERRORISM?

Mathematicians are finding patterns in apparently random acts of terrorism that may provide clues as to how to how we can thwart such attacks *before* they take place

WORDS ANDY RINGWAY

[illegible][illegible][illegible]

There is a large body of research on the effects of the environment on the development of the child. The research shows that the environment has a significant influence on the child's development. The research also shows that the environment can be used to promote the child's development. The research shows that the environment can be used to promote the child's development. The research shows that the environment can be used to promote the child's development.

DEMAND FOR DATA

At the same time, Johnson was not overrating power and a ship was built. The first trial of the ship took place in the summer of 1901. The ship was built by the same company that built the ship that was built by the same company.

"After a terror attack, it's pretty standard for people to say, 'He was a really decent person'. But it's much more about the groups they were in."

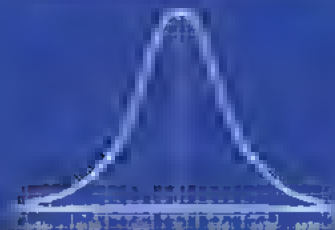
WHAT IS A POWER LAW?

The power law is a way to describe the relationship between two things, and states that a change in one thing results in a proportional change in the other thing. Take a square, for example: If you double the length of its sides, its area is increased four times, or by a power of two. Such relationships exist in all kinds of phenomena, from earthquakes to income levels.

Plot these power law relationships on a graph and you'll see that the most common things are those at the smallest scale, whether that's the level of income or the size of earthquakes. But there are also a few extreme events, like massive earthquakes or huge incomes. That's not true of other things: plot people's height on a graph and you'll get a bell curve, in which most people are towards the middle and extreme events are much less likely.

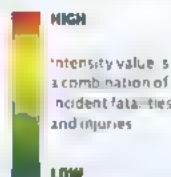
When it comes to terrorism, the power law describes the relationship between the number of events and the number of people killed. It tells us that the 9/11 terror attack was not an anomaly – such an event is likely, statistically speaking, to occur again.

Written out, the power law is fairly simple: $Y = kX^{-a}$, where X and Y are two variables that you're looking at the relationship between, say the number of terrorist incidents and the number of people killed. It is a constant, something that doesn't change over time and is the law's 'exponent' – the 'power' bit of the equation that shows how much Y changes as X increases or decreases. With terrorist incidents, it was found to have a value of 2.51.



45 YEARS OF TERROR

Heat map showing all known terror attacks between 1970 and 2015



Source: Global Terrorism Database

Both of them were harnessing data from the Global Terrorism Database (GTD), a record of terror attacks around the world since 1970.

"One of the key problems with scientific approaches to trying to understand terrorism is getting the data," says Clauset. "For the most part, terrorists don't record their activities in nice, structured formats. If you can't measure it, you can't do science with it."

The task of recording data on terror incidents has been taken up by staff and students at the University of Maryland, home of the National Consortium for the Study of Terrorism and Responses to Terrorism (START). Here, computers use natural language processing to sift through 50 million newspaper articles per month and find reports of attacks. It's then down to a team of 10 analysts, helped by student volunteers, to read through the 16,000 articles the computers pick out per month and sift out any mistakenly identified

Below: Map showing all known terrorist attacks past 45 years

as being terror-related. The articles weeded out are fed back to the computers so their artificial intelligence system can continually improve. The analysis then records 120 different variables about each attack such as the weapons used, the types of target and the number of people killed. The data they generate is released in chunks annually and is freely available on the GTD website.

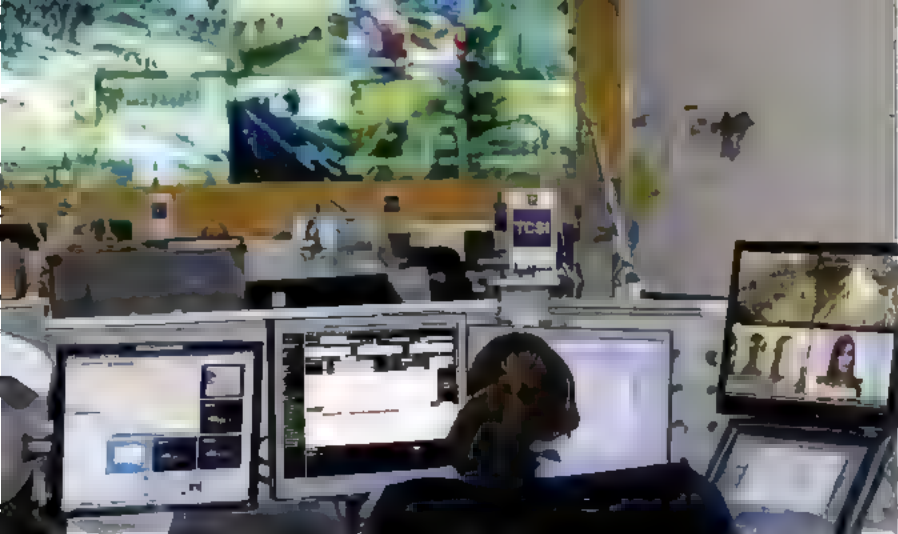
The data isn't perfect, because it relies on press reports. "There is inherently a bias," says Clauset. "If an event kills someone, it's much more likely to end up in the news media. If it's obviously terrorism, it's much more likely to be written about as terrorism. Small scale, non-lethal terrorism not caused by any group is under-represented." But it's the best data there is, and when it's analysed it shows the power law in terror attacks, just like data from conflicts around the world.

The discovery of the power law relationship between the number of attacks and the number of

"One of the key problems with scientific approaches to trying to understand terrorism is getting the data"

people killed allows forecasts to be made. "It allows us to extrapolate in a mathematically principled manner to make statements about events that are incredibly rare."

It's this kind of extrapolation that led to Clauset's forecast that the chance of another terrorist attack on the scale of 9/11, that killed 2,996 people, is 30 per cent over the next 10 years. The maths can build expectations about the frequency of



ABOVE Inside a Special Operations Room run by London's Metropolitan Police

large-scale terror events, says Clauset. “But it doesn’t allow us to predict when, why or how the next event will happen.”

Some researchers, though, are using maths to try and predict who will be behind the next attack.

EXPLANATION REQUIRED

Before getting to the point of making predictions there are other big questions to answer, such as why this 2.5 ‘power law of war’ exists in the first place. It’s especially given that the conflicts it describes are so different. “Some conflicts are Marxist, some fascist, it’s not the terrain because wars are in the jungles, some in the desert, so it must be something else,” says Johnson.

The first clue comes from the conflicts where the 2.5 power law doesn’t hold, such as World War II or the Spanish or American civil wars, where the conflicts were between two or more fairly evenly matched sides. In contrast, the conflicts where it does hold are asymmetric, involving two or more sides with very different resources at their disposal in terms of weapons and people. “We thought about what we see when we heard about attacks in places like Iraq or Colombia. They sound like a loose arrangement, where groups come together to do something and then vaporise,” says Johnson.

When the number of these insurgent groups is compared to the sizes of the groups, something familiar pops out – the 2.5 power law. In other words, the distribution of the sizes of the groups is almost identical to the distribution in the scale of attacks, with lots of small ones and a handful of very large ones. After all, it’s logical that the handful of large groups will be able to carry out far more destructive attacks than the vast number of small groups or ‘clusters’ of fighters.

By cluster, we don’t necessarily mean that the members have to walk round in a bunch. Like kids

in a playground,” says Johnson, “but that they are coordinated in some way, such as by some means of modern communication. So it can apply to a cluster of people in the desert during the Iraq era, but it also applies to more tech-savvy situations of a group of terrorists located in different places.”

The evidence for the number of groups and their sizes comes from groups identified on the ground. “It’s impossible to know the size of a cluster carrying out attacks,” says Johnson. But what is easier to get data on are the online groups of individuals who support a cause or ideology. In fact, the data is free & available, as most groups are visible online to everyone on the internet.

Johnson and his colleagues studied pro-ISIS groups that share operational information, such as advice on financing terror attacks or how to avoid drones. Where Facebook shuts extremist groups down quickly, pro-ISIS groups seem to be more prevalent on other online platforms, which perhaps have fewer resources to check what’s being posted. In a study of open-access information on the platform VKontakte, based in Russia, Johnson found 186 pro-ISIS groups with over 100,000 followers. Although groups were shut down by moderators within weeks of being created, the members would just go on to form a new aggregate or join another existing one. If a these groups that followed the power law in their scale. And this fluid online world of ISIS support, where groups coalesce, disappear and reform, suggests a means to thwart these groups – split them up before they have time to form larger, more deadly groups.

IDENTIFYING POTENTIAL TERRORISTS

Having characterised this ecosystem of online groups, Johnson and his fellow researchers have now shifted their attention to how individuals move through them, finding groups that match



ABOVE ISIS fighters on the border between Syria and Iraq in 2014

“After a terror attack, it’s pretty standard for people to say, ‘He was a really decent person’. But it’s much more about the groups they were in.”

their interests and shifting to new ones when groups are broken up. They found that despite there being many possible ways to move around, certain patterns emerge and that individuals can be described in just a handful of ways. Some people, for example, will at some point express extreme views that their account will be banned by moderators, while others will delete their own accounts, perhaps through fear of being linked to an extremist group.

To better understand how individuals move (though these online ISIS-supporting groups Johnson turned to a ‘stochastic walk model’, which predicts how people move through an imaginary 3D space. In this case, that space is the online ecosystem of pro-ISIS groups, and the destinations are being getting banned, self-deleting or something else. Stochastic processes are those that randomly change over time and are found everywhere, from the fluctuations of electrical currents to the movements of gas molecules.

Not only is this allowing Johnson to develop timelines of movements of individuals through this online world, it’s also allowing him to study what determines an individual’s ultimate destination (be banned or otherwise). “Part of it is the groups they pass through,” he says. “This is what we’re working on now. Is it worse if I go through two extreme groups without having a more spiritual group in-between, or is it worse if I go through a couple of spiritual groups and then on to an extreme one?”

It’s the people who end up being banned, the ones posting the most extreme content, who are of most interest to the author, he says Johnson, because they are the most likely to carry out an attack. Fortunately those who get banned most quickly tend to follow similar patterns in their movements, making them more predictable. And how this can be used doesn’t end with ISIS. Other forms of extremism exist online, such as anti-left and far-right ideologies, and the findings about the movements of pro-ISIS individuals are likely to be more widely applicable.

The focus on groups and their influence is the right way to think about this, says psychiatrists Professor Alex Haslam at The University of Queensland in Australia. An expert on how groups influence individuals, he was involved in the HMP Prison Study in 2002 that saw volunteers spending time in a mock prison to see how they behaved.

After a terror attack, it’s pretty standard for people to say, ‘He was a really decent person. I’m shocked at this,’ says Haslam. “But it’s much more about understanding the groups they were in.”

Being able to predict who is more likely to engage in terrorism from their trajectory through online groups leads to an ethical question: what to do when someone who seems to pose a threat is identified? Johnson sees it simply as “an additional piece of information that the legal system can decide how to use,” but Clauset argues against it.

The idea of looking at precursor signals or trajectories isn’t unreasonable,” he says, “but I think the standards for believing these things are correct must be very high, because we are talking about people’s lives here.”

Andy Ridgway is a freelance writer and editor who specialises in science, health and digital issues.

MEET THE MAMMOTH HUNTERS

WORDS BY HELEN PALMER

Melting permafrost and a market for mammoth tusks is fuelling a new, dangerous trade in deepest Siberia

In the Siberian summer, the Sun bakes the banks of the Khatanga River in the region's north-east, straggly larch and the spruce trees provide over a patchwork of lichen and moss. It's one of the world's last great wildernesses, but its beauty is being eroded – literally – by an underground business that is booming. Every year, clandestine crews of men head to the region to look for hidden treasure: the tusks of woolly mammoths that lie frozen in the permafrost. It's dirty, backbreaking work. They sleep in makeshift tents, live off canned food, another pit vipers, and operate illegally, digging the mammoth remains from the earth with a level of expertise never seen before. The sell the tusks at public auctions, creating a new 'gold rush' – not in precious metals, but in body parts. And amidst it all, concerns are mounting that the practice could have a devastating effect on the mammoth's modern-day cousin, the African elephant.



The mammoth graveyard

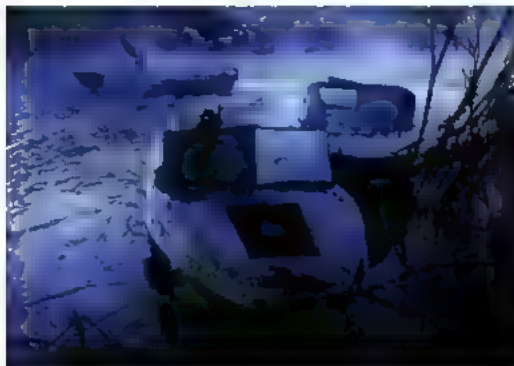
Fifty thousand years ago, Siberia looked very different from how it does today. Instead of forest and scraggy tundra, the region was blanketed in lush grasslands and fertile soils, and herds of woolly mammoths roamed the open plains. There little by little, towards the end of the last Ice Age, their numbers started to diminish. No one really understands why. Some blame human hunting, some climate change, others a bit of both. What we do know is that they disappeared from Siberia 10,000 years ago, then from their final hiding place – a northerly island called Wrangel – just 3,700 years ago. Now Siberia is a massive mammoth graveyard, and it's estimated that the remains of

Mammoth facts

Life story: *Shorebirds are everywhere!*
Lifespan: 60 years
Home: Living relatives: *Wilson's phalarope*
(seabirds) (shore)
Education: *Wrote songs and songs*
having both played a part in the
musical's success
Adult size: Adult male: 100gms up to
 150gms and weighed up in some
 to ones (that's about the size of *them*)
(smaller birds)



James P. French is a senior research advisor at the Center for Strategic Studies, RAND Corporation, in Santa Monica, California. He is also a senior research advisor at the Center for the Study of the Presidency and the Executive Branch, in Washington, D.C.



Sold down the river

[illegible]

The clandestine crew

[illegible]

While some people have a different perspective on the matter, the fact remains that the world is a more complex and interconnected place than ever before. As we move forward, it is essential that we continue to work together to address the challenges we face and to build a more just and equitable world for all.



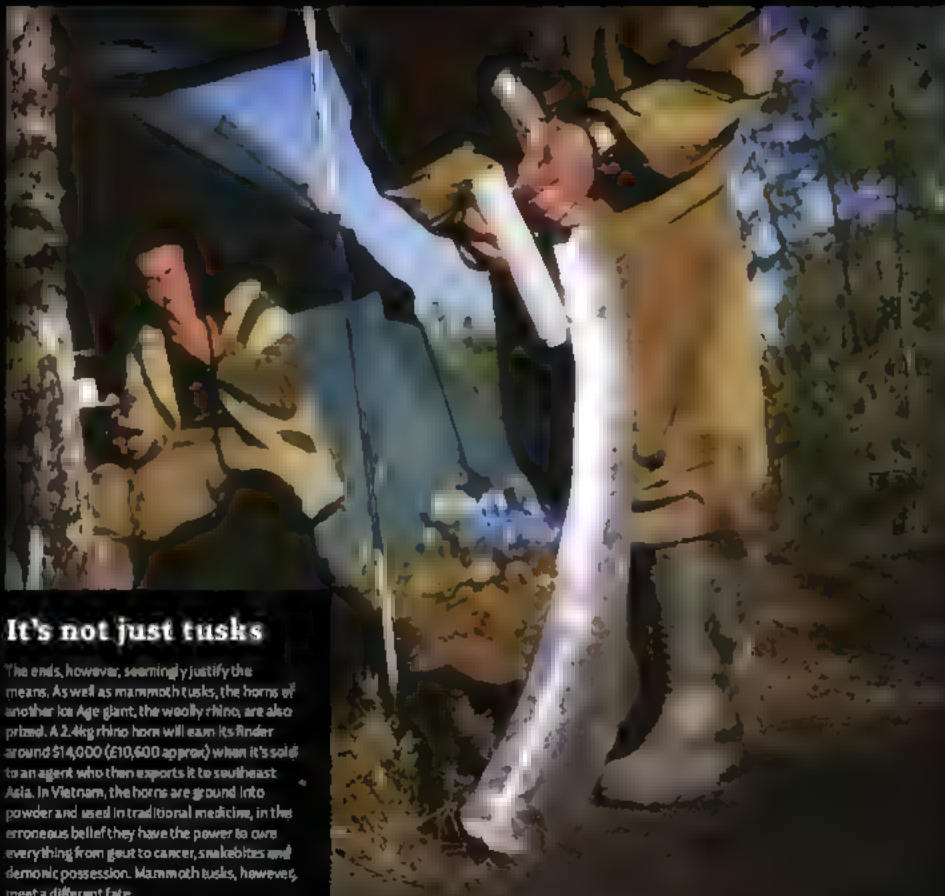
Blast off!

They blast the riverbanks and crumbling permafrost cliffs with jets of water, drawn from the nearby river or sea. Power comes from makeshift petrol-powered water pumps, converted from the engines of snow mobiles and other vehicles. The pressurized cannons reduce the icy permafrost to a slurry of mud, pebbly sludge, which then oozes back into the waterways. Any body parts that are liberated come tumbling to the ground. Because the permafrost has remained frozen since the end of the last ice age, some 11,700 years ago, the remnants are perfectly preserved. Infant bones are kept, but everything else – bones, tools and trash fragments – are discarded and left to the elements. In the years that follow, these will either wash or weather away.



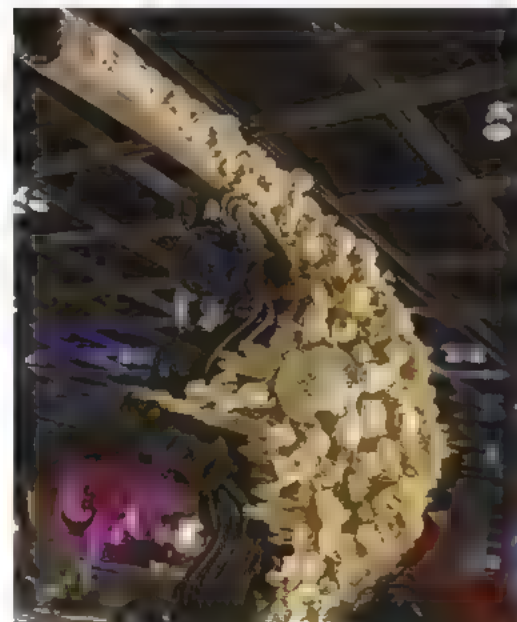
Sleeping on the job

If one knows how many tuners have been injured or killed. Because the operation is illegal, no records are kept. Although the inside of a fresh tunnel is rock hard, there's a rich inside of low oxygen levels, and outside of landfills around the entrance to the caverns. The most dangerous element, however, isn't the tunnels but the underways. The rocky rivers are riddled from the disintegrated sediment, and full of driftwood and felled logs. These men crashed their boat at speed near a spot where two prospectors drowned last year. When a 3-man rescue mission found them (it's still daylight at that time), they were pressed out in a boat full of waterlogged equipment.



It's not just tusks

The ends, however, seemingly justify the means. As well as mammoth tusks, the horns of another ho Age giant, the woolly rhino, are also prized. A 2.4kg rhino horn will earn its finder around \$14,000 (£10,500 approx) when it's sold to an agent who then exports it to southeast Asia. In Vietnam, the horns are ground into powder and used in traditional medicine, in the erroneous belief they have the power to cure everything from gout to cancer, snakebites and demonic possession. Mammoth tusks, however, meet a different fate.



Ethical ivory?

A d u p e t e r i s e d a g a i n s t t h e
a d u l t e d e n d u p h a n d h a n d l i n g
w h e n t h e y a r e i n t h e a n t h e n t
b u t t h e y a r e d e a l t w i t h a s w e n o
w h e n t h e y a r e d e a l t w i t h a s w e n o
g e n e r a l l y a r e d e a l t w i t h a s w e n o
w h e n t h e y a r e d e a l t w i t h a s w e n o
w h e n t h e y a r e d e a l t w i t h a s w e n o
g e n e r a l l y a r e d e a l t w i t h a s w e n o

1. The first one is the one who is today's guest.
 2. The first one is the one who is today's guest.
 3. The first one is the one who is today's guest.
 4. The first one is the one who is today's guest.
 5. The first one is the one who is today's guest.
 6. The first one is the one who is today's guest.
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 8. The first one is the one who is today's guest.
 9. The first one is the one who is today's guest.
 10. The first one is the one who is today's guest.

Helen Pilcher por de stive povas tenero de la eksa reĝino
 «Willy» de la reĝino. De la Stak. The King
 «New» de la eksa reĝino. De la Stak. The King
 @helenpilcher

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CAN WE TRUST ARTIFICIAL INTELLIGENCE?

1. *Journal of the American Medical Association*, 1997; 277: 1039-1043.

“IT’S THANKS TO DEEP LEARNING THAT WE HAVE SIRI, CORTANA AND ALEXA”

Deep learning does it all: face recognition, speech recognition, language translation, automated game-playing. It is an approach that has transformed the field of artificial intelligence (AI) and is without doubt the AI flavour of the decade. It works amazingly well.

But increasingly questions are being asked about transparency. Exactly how does deep learning work? Can we trust it to work for safety critical applications such as self-driving cars? We generally like computer algorithms to be as transparent and revealing as possible – and this is not the case when it comes to deep learning. In essence, deep learning is really a clever rebranding of an earlier computer learning method called artificial neural networks (ANNs). Dating back to the beginning of computers, ANNs are computer programs that simulate networks of neurons – like those in our own brains. They’re hugely simplified and don’t really work in quite the same way that real neurons work – but nevertheless, they enable computers to learn (see ‘How a neural network works’, opposite).

EARLY DAYS Research on neural networks started in the 1950s and 1960s, but it was not until the 1980s that it became clear that neural networks were not as good as some other approaches in machine learning (the branch of AI dedicated to helping computers learn from data in order to make classifications and predictions). As a result, research in the area began to wane by the early 1990s, and learning methods that relied on clever statistics started to dominate.

This all changed about 20 years ago. British pioneer Geoff Hinton (University of Toronto and head of Google’s Brain Team Toronto), and Jürgen Schmidhuber (IDSIA Dalle Molle Institute for AI Switzerland, introduced new, more efficient ways to train neural networks containing far more layers. Suddenly, networks could have hundreds of hidden layers – rows of neurons that sit between the input neurons, which are connected directly to the various sensors, and the output



ABOVE Jürgen Schmidhuber at 2016’s Digital Life Design conference in Munich

neurons, which provide the results. When combined with new ways of connecting the neurons to each other, the result was massively more powerful. The breakthroughs also coincided with the age of big data, cloud computing and fast processors (including graphics cards originally designed to make computer games zippy). By 2006 it was possible to create a generic ‘deep’ network: train them with vast quantities of data – in this case, huge numbers of fast computers all working in sync.

It was the start of the newest revolution in AI: deep learning works. Although still based on a very simplified model of how the brain functions, it relies on unprecedented networks of thousands or millions of neurons simulated in software. Given enough data (and today we have vast amounts) and enough computers (and today we have plenty) to enable the networks to adapt and learn in response to the data, the result is like a little software brain.

If it’s been trained to recognise faces, then this little face-recognising brain can be duplicated a few million times and placed into every camera so that when you take a photo it finds faces and ensures they are in focus. If it’s been trained to recognise speech, then the little speech-recognising brain can be placed into your phone so that it can understand the words you have spoken. If the brain has a lot of neurons, it can even run in the cloud – and when you speak, your words are sent to these remote computers which do the deep thinking, and return the results back to your device in the blink of an eye.

In the last decade, deep learning has resulted in some startling advances in the field of machine

learning. It’s thanks to deep learning that we have Siri, Cortana and Alexa, it’s because of deep learning that we have automated machine translation, face recognition, and automated captioning of images. But not everything is rosy. While these massive neural networks show some truly remarkable capabilities that speakily resemble the capabilities of biological brains, they also share another of a real brain’s properties: a lack of transparency.

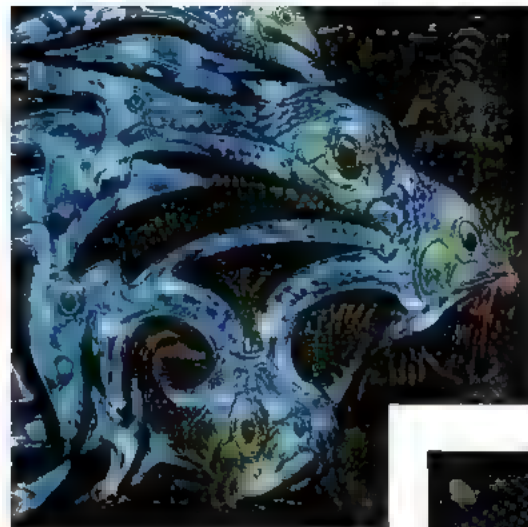
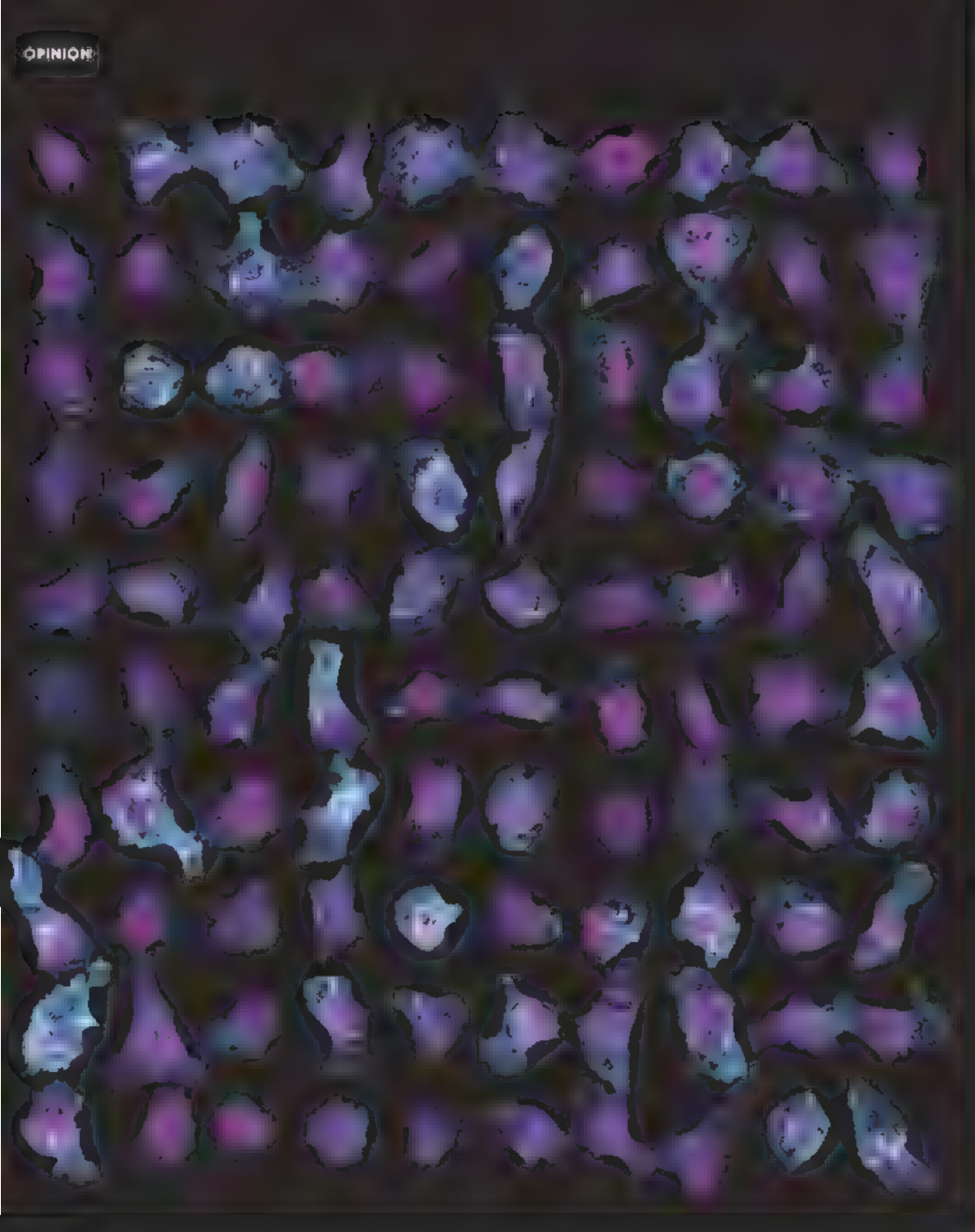
INTO THE UNKNOWN In a biological brain, we still have surprisingly little idea exactly where information is stored, or exactly how decisions are made. We know it’s all something to do with those neurons, but we can’t point to one group of neurons and say, “That’s where you remember the taste of chocolate,” or point to another group and say, “That’s where your decision to buy a new toothbrush was made.”

In exactly the same way, we have no idea where information or decisions are stored inside these giant artificial neural networks. They are black boxes to us. We cannot see inside them. In science and engineering, this is not a good thing. When we have safety-critical technology, we want to be able to prove that the technology is always going to work. For example, we already have automated trains, and we trust them because the software that controls them is formally proven to be reliable, using mathematical methods.

Today, many autonomous factories are working on autonomous vehicles, and most of them are using deep learning as part of the systems to interpret sensor data and recognise hazards on the road. Tesla, for instance, is one of the first companies to sell vehicles with an autonomous driving mode – and it’s one of the first to encounter problems. Last year, one Tesla driver placed too much trust in his car, which drove into the back of a stalled van. Tesla does warn drivers to stay alert while using the system, but Andrew Ng, founder of Google’s Brain Project, and pioneer of the use of deep learning to learn without supervision, commented on the crash, tweeting: “It’s irresponsible to ship a driving system that works 1,000 times and fails false sense of safety, then ‘BAM!’”

Other recent work by researchers at the Icahn School of Medicine at Mount Sinai, New York, has used deep learning to analyse patient records. In 2016 their deep network looked at more than 75,000 patient records and 78 diseases and was able to predict severe diabetes, schizophrenia and various cancers with high accuracy. This is valuable work that could save lives. But how does a doctor tell her patient that he’s likely to develop schizophrenia because a deep network says so? Can a doctor trust a prediction enough to start preventative care, when no explanation is given? ●





ABOVE The startling images produced by Google's DeepMind have helped bring machine learning into the public consciousness

RIGHT Deep learning is used in obstacle detection systems for self-driving cars
Project is a deep learning network that can identify its component parts of cells from 3D images

● A LEGAL CONUNDRUM
The European Union is so concerned about these new technologies that it has already adopted new General Data Protection Regulation, which refers to our rights with respect to machine learning. Due to become law in all EU member states in May 2018, Article 22 states that everyone "shall have the right not to be subject to a decision based solely on automated processing and the right to be given 'meaningful information about the logic involved' in any decision made by a computer."
These are sensible precautions, but the fact is that they are incompatible with deep learning. If your mortgage application is refused because of a deep learning algorithm, you will be legally entitled to an explanation – but it may be impossible to provide it.
Researchers are working on ways to improve this situation. Recent work from Google DeepMind suggests that some explanations could be found by using methods from cognitive psychology – running experiments on the neural networks to try to understand what they're responding to, in the same way that we run

experiments on people to understand our own brains. But if you've just had your mortgage refused and the only explanation is "the network sometimes pays a lot of attention to spending on leisure activities, so that might have been the case here," you're not likely to be happy.
Deep networks' lack of transparency isn't shared by other machine learning approaches. It's possible to use other AI techniques for most applications, and have complete, human-readable explanations. Other methods also have the advantage that they may have a better formal (mathematical) underpinning. This means a much clearer understanding of the reliability of the results can be obtained, allowing us to judge

how far we should trust the methods. But these other methods aren't deep learning – so they're not seen as 'cool' right now.
There are so many deaths caused by human drivers that making self-driving vehicles safer than us should not be an insurmountable problem. Yet progress towards this goal isn't helped when we can't quantify the risk of using deep learning for specific applications. Just as we don't understand how it works or what it will do – at least not until it's already

done it. Our roads, vehicles, buildings and cities are full of things. If the workings of the deep learning brains in our autonomous cars are unknown to us, then how can we be confident that they will work when confronted with things they haven't been tested on?
In Europe, the answer is familiar: new regulation for artificial intelligence algorithms. But we need to apply some common sense here. Artificial intelligence is not one technology: it's a thousand different approaches applied to a million different applications. Deep learning is the latest to arrive, but like all new technologies, it must be tested and certified to work safely for each specific application, before we can trust it with our lives. **Q**

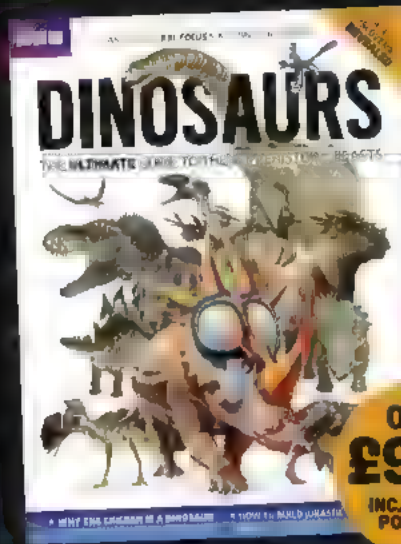
Dr Peter Bentley is a senior research fellow at the Centre for Computational Neuroscience at University College London

PHOTO: AL DAMIANI/GETTY IMAGES

"CAN A DOCTOR TRUST A PREDICTION WHEN NO EXPLANATION IS PROVIDED?"

DINOSAURS

THE ULTIMATE GUIDE TO THESE AMAZING BEASTS



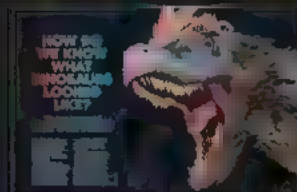
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- A timeline clearly explaining when different species lived

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HELEN CZERSKI ON AIRPOLLUTION

"MY FAVOURITE SCARF NOW SMELT LIKE THE START OF A TEENAGE LAD'S NIGHT OUT"



One day last week I was sitting in a room with a glass pane in front of a window spray can and a little new smelling fragrance.

The first test to see if the air was clean. For me, it was a simple test: I kept the fragrance in the room and waited to see if the air was clean. I kept the fragrance in the room and waited to see if the air was clean.

But when I tried the first of the three, the air was clean. I kept the fragrance in the room and waited to see if the air was clean. I kept the fragrance in the room and waited to see if the air was clean.

We know that aerosols have liquid in them, because we can hear it when the can is shaken. This liquid is a state of whatever you're buying, like spray air freshener, paint, etc. and a liquid. In a liquid, the air is a state of whatever you're buying, like spray air freshener, paint, etc. and a liquid.



Dr Helen Czerski, physicist and author of *The Physics of Everyday Things*, explains why we should be worried about air pollution

of the rest of the world. I was in a room with a glass pane in front of a window spray can and a little new smelling fragrance. The first test to see if the air was clean. For me, it was a simple test: I kept the fragrance in the room and waited to see if the air was clean. I kept the fragrance in the room and waited to see if the air was clean.

But physics of gases is a little tricky. I was in a room with a glass pane in front of a window spray can and a little new smelling fragrance. The first test to see if the air was clean. For me, it was a simple test: I kept the fragrance in the room and waited to see if the air was clean.

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YOUR QUESTIONS ANSWERED

By Tracy Evans

EDITED BY EMMA BAYLEY



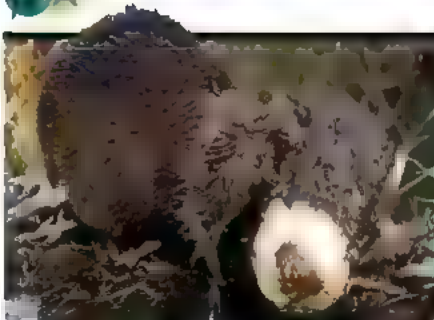
Which plane has the biggest wingspan?

TRACY EVANS

The passenger plane with the biggest wingspan is the Airbus A380 – a monster double-decker plane that carries 550 people, with a wingspan of 80m. But the overall plane with the biggest wingspan will soon be an aircraft that carries no passengers at all.

The Airbus consortium of the world's aircraft manufacturers has helped create the Stratolaunch. This will be an aircraft with six 47 jet engines and a twin fuselage (the flight crew are all in the right-hand one, and passengers sit in the left one). The amazing machine will carry rockets high into the atmosphere, launching satellites cheaper and more reliably. It's still under construction, but its wingspan will be 117m.

The Stratolaunch will have the longest wingspan of any aircraft ever built. It will be used to launch satellites into space.



Why do beavers build dams?

SARAH CONNORS, 14, ABERYSTWYTH

Building a dam is synonymous with beavers, the cute little animals. Using their brains from trees they have felled, these ingenious rodents seek to create a catchment pool to store water, which they use for swimming and as a refuge. Beavers also build dams to create a series of lodges, made of mud and sticks, which they use as a home. The lodges are built in the middle of a pond, and the beaver enters through a tunnel. The largest lodge found in America measures over 500m in length – though that's a very long time to be in one place! Beavers also build dams to create a series of ponds, which they use for swimming and as a refuge. Beavers also build dams to create a series of ponds, which they use for swimming and as a refuge.

How long do six pints of lager stay in my system?

CAROLINE PAGET, 14, ABERYSTWYTH



There's no simple answer. The rate at which you can break down alcohol depends on many factors, including your age, sex, weight, metabolism, and how much you've eaten. As a general rule, it takes about one hour for your body to break down one unit of alcohol. So if you've had six pints of beer, it will take about six hours for your body to break down all the alcohol. In other words, at least some alcohol will still be in your blood the morning after the night before.

IN NUMBERS

2.647

19.7M

19.7M

19.7M

19.7M

Why does music make us feel good?

AMMAR EL-BEIK (AGE 12), WILMINGTON

At a basic level, it is linked with how our brains have evolved to find a rewarding, to look for and find meaningful patterns in sound. Research suggests there is something particularly satisfying about a piece of music that is in some ways familiar, but also contains a few surprises. Music can also make us feel good by amplifying our current mood (think of the pleasure of warbling a sad song when you're feeling low), it can also trigger fond or poignant memories. Then there's the social side: singing along with friends to a new track from your favourite band fosters a powerful sense of belonging.



Few things can stir the emotions like listening to music.

What is at the centre of a gas giant like Jupiter?

MAN FARMER, NOTTINGHAM

This is one of the key questions astronomers hope to resolve with data from NASA's Juno mission, currently orbiting Jupiter. Jupiter's atmosphere is made up of around 90 per cent hydrogen and 10 per cent helium, so computer models suggest its core may be made from metallic hydrogen, a bizarre form of the element thought to exist at extreme pressures.

TOP 10

SLEEPIEST ANIMALS

BY HOURS SPENT SLEEPING PER 24 HOURS



1. Koala 20-22

2. Sloth 20

3. Brown bat 19.9

4. Giant armadillo 18.1

5. North American opossum 18

6. Python 18

7. Owl monkey 17

8. Human infant 16

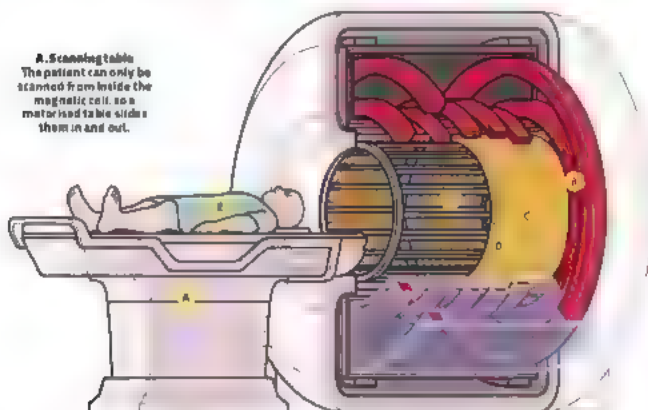
9. Tiger 15.8

10. Tree shrew 15.8

HOW IT WORKS

THE MRI SCANNER

Magnetic Resonance Imaging (MRI) takes advantage of the fact that the nucleus of a hydrogen atom (a single proton) behaves like a weak compass needle. In the presence of a strong magnetic field, the hydrogen atoms will align themselves, but a radio signal of the correct resonant frequency will cause them to deflect slightly. When the signal is removed, the atoms return to their equilibrium state and emit a radio signal of their own. An MRI scanner can detect these signals and use them to map the distribution of molecules with lots of hydrogen atoms – ie, water and fat. In this way, it can create detailed images of the inside of the body.



A. Scanning table
The patient can only be scanned from inside the magnetic coil, so a motorised table slides them in and out.

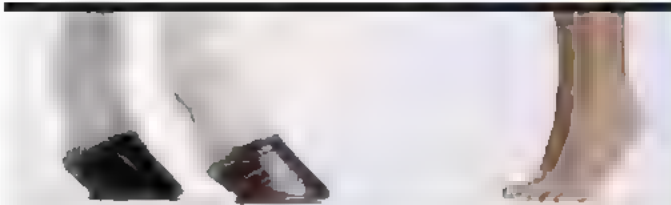
B. RF system
An antenna produces a radio signal to 'nudge' the hydrogen nuclei and listen to the answering radio wave they emit.

C. Liquid helium
Liquid helium is pumped through an enclosing jacket to cool the superconducting magnets almost to absolute zero.

D. Main magnet
Superconducting magnetic coils produce a magnetic field of 1.5 teslas – that's about 300 times stronger than a fridge magnet.

E. Patient
The high magnetic fields mean that patients with cochlear implants, pacemakers or embedded shrapnel usually can't be scanned.

F. Gradient system
A second coil distorts the main magnetic field so that the resonant frequency of the protons varies according to position.



Why don't horses have toes?

LESLIE WATERS / HIGH WYCOMBE

Early horses such as *Hyracotherium*, which lived 55 million years ago, did have multiple toes, but they were much smaller animals. For taller animals, excess weight at the end of their legs has a much bigger impact on their speed. A

recent study at Harvard found that one broad hoof is almost as strong as multiple smaller toes, but much lighter. Nature, selection has gradually discarded the horse's side toes and widened the middle one to increase running speed. **EW**

Why do ants walk in a line?

ANJALI NAIR / NOA

Ants are highly social insects thriving in colonies of millions of individuals that work as a team. Good communication skills lie at the heart of their success. They rely heavily on chemical scents called 'pheromones', to defend territories and exchange complex information – from the location of food sources and nest sites, to the presence of predators. Each ant species has its own chemical vocabulary of up to 100 pheromones which can be secreted to form specific scent trails. The tips of their antennae translate the chemical 'words', thereby guiding the ants, in a line, to or from the desired destination. **AN**



Ants walk in a line because they're on the march, but they're slowly abandoning their march.



Does sea air really make you sleep better?

TIM ROWLAND / A SANJ

Take a coastal walk and the chances are that you will sleep better according to a 2015 study by the UK's National Trust. However, there is no evidence that sea air in itself will make you sleep better. At the time, people attributed that sleepiness to certain ions or ozone in sea air. In reality, we probably sleep better after a trip to the seaside because we have had a satisfying amount of exercise and have been lulled by the rhythmic sound of the waves. Those that live their daily lives by the seaside don't tend to report in poorer sleep. **TR**

What could explain the Star of Bethlehem?

PAUL WALKER, TO MERRIDGE



Ancient Chinese records report the appearance of a bright comet in 13BC and also the sudden flare-up of a star in 4BC – both around the time when Christ is now thought to have been born. However, some researchers have claimed these events lack the astrological significance of 'portents' involving the Moon and planets, which would have attracted attention among scholars of the time.

This has led to the emergence of two top contenders for explaining the Star of Bethlehem. The first is a so-called 'occultation' in 6BC, when the Moon appeared to pass in front of Jupiter in the night sky. The second contender is an unusual triple conjunction of Jupiter and Saturn which took place in 7BC, when these two great planets repeatedly appeared close to one another. **PM**

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WHO REALLY DISCOVERED?

15-1116



TACHARY BLATT, BENILWOLFF

Imagination underlies our ability to anticipate different futures and to reflect on alternative pasts. Arguably, it's what distinguishes us most profoundly from other animals. It means we can learn from past experiences (PFRD takes a queer with me, I could have caught the doc!) and use can be prophetic about the possible

outcomes of future scenarios ("I'll trek across the desert without any food or water. I will get hungry and thirsty"). This makes it incredibly adaptive and is the secret to our superlative planning and problem-solving skills. Once imagination evolved, it also unlocked the gifts of storytelling, fantasy and wonder. ■

Is vaping safe?

STACEY HUGHES, 617 E. 7th, McAllen, TX 78501



The most recent research shows that vaping is much less bad for you than smoking. If you already smoke cigarettes then switch to vaping completely to cut cigarettes down to a few a day to protect your health. But smoking is so bad for you that you can't switch to vaping and still come out ahead. Quitting every day for 70 years gives a 40 per cent chance of early death, while lifelong smokers have a 90 per cent chance of dying before 70.

The real question is—**are you safely taking up recreational vaping, even if you don't already smoke?** The evidence for this is much less clear. Nicotine itself doesn't cause cancer, and vape juice

doesn't contain any of the 70 known carcinogens that are present in tobacco. But it does contain other chemicals, such as propylene glycol. When this is heated by the electric element in the cigarette, it can create formaldehyde, which is carcinogenic. The different flavor chemicals used in vaporizers are all organic compounds, and these can also be altered by the heating element.

Veeping has only been an aid for a decade, so it's still too soon to be sure of long-term effects. Since cigarettes will get you hooked on nicotine just as surely as tobacco does, I don't yet seem wise to take up a whole new addiction. **W**

THE UNIVERSITY OF AUSTRALIA PRESS, 1988. Pp. 220. \$25.00. ISBN 0 521 25413 5.

WHAT IS THIST?

Welded

This aerial photo shows part of Sears Point, an area of high land that juts out into the San Pablo Bay in northern California. Over 300 hectares of it are being restored to marshland, as this provides an important habitat for local wildlife and reduces the risk of flooding in nearby towns. The circular 'marsh mounds' seen here prevent waves from storming and carrying away the sediments marsh plants need to grow.



DAVID SMITH, LONDON

The longest known single journey was that of a *Doctor Who* postcard in a bottle thrown into the sea at Tyne and Wear in 2011. This turned up 17 months later in Perth, Western Australia – over 14,500km away. But in 1929 German marine scientist dropped a bottle into the Indian Ocean with instructions for the finder to report where it washed up and then throw it back. This floated for six years and covered 25,000km. **AW**

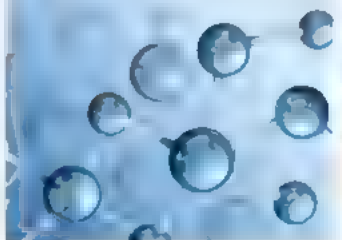
TONY KARGER NORFOLK

The expansion of the Universe only significantly affects space and time on scales bigger even than entire clusters of galaxies. Below this, the size of objects is dictated by far stronger influences, notably the force of electromagnetism in the case of atoms. Extremely sensitive measurements have found no evidence that the fundamental properties of atoms are anything other than constant. **AM**

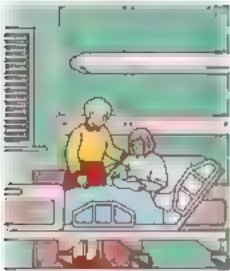
SANTEE by Michael



Experiments in the ISS have shown that young sprouted seedlings do grow in microgravity, but they don't move with the same. The seedlings grow faster and they tend to grow less pointed downward so much. DNA analysis shows that several plant genes are more active to space (i.e. extracellular) waiting to find out the long term effects on larger plants. **W**



HOW CAN I LIVE TO BE 100?



Life expectancy figures normally assume mortality rates will stay the same, but medical and safety improvements are constantly reducing them. A new Danish model that takes this into account found that children born in the developed world today have a 50 per cent chance of reaching 100.



Women live longer than men, and not just because they tend not to fight wars. Japanese researchers created mice without a father by combining two female genomes. Their lifespan was extended by 30 per cent. Men may be engineered for size and strength at the expense of durability



in the UK, the sun is only bright enough to make vitamin D in our skin between April and September. Vitamin D has been shown to help proteins in your cells keep the correct 3D shape. Misfolded proteins are associated with ageing diseases such as Alzheimer's and Parkinson's.



Daily exercise slows the gradual loss of heart muscle and bone density as we age and reduces the risk of falls. Once you can no longer walk 400m (0.25 miles) in five minutes, your chance of dying in the next three years rises by 30 per cent.

PHOTOGRAPHY BY JAMES HARRIS

POST NAME: LUTHERBURY

For many people, there is something disturbing about the clown's make-up that renders their facial expression as an unnatural, fixed grin or smile. This means we can't read their true emotions, putting us on edge. It's probably no coincidence that many of the most infamous horror characters also conceal their faces in some way - think of the Scream mask, or Leatherface from *The Texas Chainaw Massacre*. When the clown also behaves aggressively or menacingly, the contrast with their playful costumes and grinning features just adds to the creepiness. But content is everything: children and find friendly, silly clown costumes hilarious.



PEARL GOODWIN ELLIS

A 2008 study found that 68 percent of dogs regularly eat grass but only 22 percent of them are sick afterwards, and it doesn't seem to be because the dog is ill. Wolves also eat grass, and it may be that this helps to purge their intestines of parasites. Dogs may have inherited this instinct from their wilder ancestors, though most dogs are tame, at least when they're not.



• BEN CHILDS, COLCHESTER

Believe it or not, they get lighter. USB drives use Flash memory, which means the (the ones and zeros of your data are stored on transistors. When you save data, a binary zero is set by charging the float gate of the transistor, and a binary one is set by removing the charge. To charge it, we add electrons, and the mass of each electron is 0.000910938261(60) amu. This means that to simply flip

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drive (which mostly holds zeros) weighs more than a full USB drive (which has ones and zeros). Add data, reduce the weight. However, you would need to weigh more USB drives than exist on the planet together at once before the difference in weight became easily measurable. es



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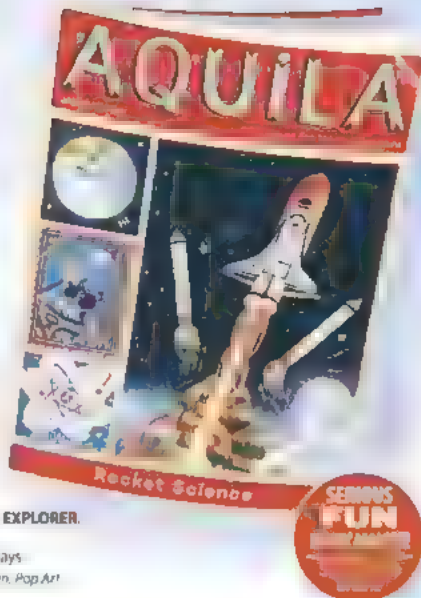
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This Vulcan stove fan is driven using Stirling engine technology using the heat from a fire. It requires no electricity or power source such as batteries or AC power. The fan circulates the stove's warmth quietly, efficiently and inexpensively.



Newly invented, this tractor beam magnet contains a number of magnets in a special arrangement. The special arrangement creates a unique magnetic field that can hold another magnet at a fixed distance away.



First you notice that it is vibrating, then you notice it is something being pulled towards the sun. A string of iron magnets keeps vibrating while some magnets and copper coils and solar panels keep it rotating.



A very interesting, simple and fun toy. When the lower portion of the glass sculpture is heated, the liquid comes into the upper section and appears to boil furiously. Then hold the top section and liquid returns to the bottom.



Ferrofluid is a runny fluid that is magnetic. Hold a magnet to it and watch how it reacts. Some of the shapes you can create are mesmerizing.

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

CHRISTMAS 2017

EDITED BY JAMES LLOYD



How much of our communication is linked to the actual words we speak?

Words are a critical part of communication, but there are many other ways in which we express ourselves. Take the voice, for example. You can't see me right now, but you could have a good guess at my age, geographical origins, mood and health, all from the way I'm talking. Our voices change throughout our lives. As women go through the menopause, for instance, their voices tend to get lower in pitch, while men's voices get higher as they age. There are social and cultural factors, too. Prior to puberty, boys and girls should (theoretically) speak at the same pitch, because they're the same age, but we find that boys speak with lower voices – they're already picking up characteristics from the men around them.

And we communicate with our bodies as well, don't we?

Yes, we use our facial expressions, eye movements and body language. A lot of this is intuitive and outside our awareness: after a conversation you tend to remember the gist of what's been said, but it can be harder to pull out the subtler things going on. You can train yourself to pick up on people's (usually) facial expressions, but a lot of communication is down to the other person's interpretation of the interaction.

Can we train ourselves to use body language more effectively?

It must be possible, because if you look at actors, dancers and singers, they learn to use their bodies in an aware way – you believe in their performance. But with people who've had a bit of body language training, it's like we can see their effort. It's the same with bad acting. We're so good at using these cues to work out someone's state of mind that as soon as something's not quite right, we pick up on that lack of authenticity.

Laughter is something else we often fake. How do you spot a fake laugh?
If you think back to the last time

you couldn't stop laughing, that's the most spontaneous kind of laughter. You just have to let it work its way through – you're lost to the laughter for a while. If the laughter stops and starts quite quickly, then it's being used more communicatively. But this more controlled type of laughter is a useful social skill. We're used to changing a mildly difficult situation into a positive, safe one.

Why did laughter come about in the first place?

We're not the only animals who laugh. We see it in rats – they make a kind of ultrasonic squeaking when tickled – and great apes, and there's probably more out there too. Whenever we've found laughter, it's associated with babies being tickled by their parents, so it's

We think we're laughing at jokes, but we're laughing just as much for social reasons

inbuilt, it seems to be in social bonding. It may be an invitation to play – a way for animals to learn and explore social roles without getting hurt. It's the same for adult humans. We think we're laughing at jokes and humour, but we're laughing just as much for social reasons – to show that we like and agree with the people we're with.

What impact is modern technology having on communication?

There have always been ways to communicate that aren't face-to-face. My grandparents' generation lived at a time when the post was so quick they could have a conversation using postcards!

We're very good at exploiting new technologies to help us share messages. One of the first things we did with mobile phones was to send text messages, which no one saw coming. There's some data from (revolutionary psychologist) Robin Dunbar's lab which shows that face-to-face interaction – live or on-screen – leads to people feeling happier and laughing more than just listening to each other, and then the happiness drops off again for text-based interactions. But this study was done a few years ago, and I wonder if that's changed now with all the ways we use GIFs and emojis. Whatever happens, I think communication is always going to be rooted in face-to-face interaction, because that's how we learn to use speech as we grow up.

Can emojis ever be an effective way to communicate?

We have a long history of using punctuation to change the emotional tone of our writing, and that's just what we're doing with emoticons and emojis. We're not going to be comfortable sending emojis to everyone – I'm unlikely to start sending messages full of them to the dean of my university – but they can show you things you didn't know you needed. I was struck by the number of emojis for approval: the 100 per cent sign, OK fingers, clapping hands, thumbs up. It's great to give somebody feedback without having to write a long essay on why. I thought that was a funny tweet.

What do you hope your audience will take away from your lectures?

I hope I'll be able to do justice to the sheer complexity of communication, from basic signals like "I'm a dangerous wasp" through to the possibilities of the human voice. And one of the really powerful things about the Christmas Lectures is that they can show there are all these different ways of being a scientist. Male, female, younger, older – there's not just one way of doing it or one route to getting there. Hopefully that'll help to shift some of the stereotypes.



Sophie Scott will be presenting this year's Christmas Lectures

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creatures on show were a praying mantis, a ring-tailed lemur and an impossible baby orangutan.

DAVID ATTENBOROUGH 1971

Attenborough's six lectures on *The Language Of Animals* shattered the cardinal rule of showbiz: "never work with animals or children". Among the



CARL SAGAN 1977

In possibly the most iconic lectures of all, Sagan discussed our place in the Solar System and the game-changing discoveries made by the Mariner 9 and Viking missions to Mars. It was a fertile time for space exploration, with the twin Voyager spacecraft launched just a few months earlier.



SUE HARTLEY 2009

The botanical world was brought memorably to life by Hartley with chocolate fountains, giant narrows and mouth-burning chillis all helping to demonstrate the ways in which plants cling to survival, and how we've manipulated plants to suit our own needs.

02

CHRISTMAS
BOOK
GUIDE

CURL UP WITH A BOOK

There's no time like Christmas to get lost in a book. Here are 13 of our favourite long reads of the year



THE ANIMALS AMONG US

JOHN BRADSHAW
£20 ALLEN LANE

Why do we love our pets so much? Beyond cuteness...

Weaving together psychology and evolutionary biology, this book will give pet owners a newfound appreciation for their furry friends.



BEYOND INFINITY

EUGENIA CHENG
£12.99 HODDER BOOKS

It takes a talented writer to bring the concept of infinity to life. Cheng makes maths a delight. Discover why some infinities are bigger than others, and why there's always room at an infinite hotel, even if it's full.



CORDE, LA FINE

EMMA FENN
£14.99 CON BOOKS

Dispelling the myth that testosterone creates a deep-rooted division between the sexes and discussing what this means for the society we live in.



ANGELA'S ASHES

The second book on our list to tackle gender stereotypes, Saini discusses how centuries of science have painted a distorted picture of sex differences and the impact this has had on women in society and how we're finally beginning to redress the balance.



OTHER MINDS

PETER GODFREY-SMITH
£20 WILLIAM COLLINS

Godfrey-Smith peers into the minds of cephalopods, revealing what the nature of consciousness is.



GASTROPHYSICS

CHARLES SPENCE
£16 SPINKING

In this breezy introduction, Spence explains how our senses are a truly multi-sensory experience. It turns out that everything from the background music in a restaurant to the shape of our plates affects the taste of our food.



TIM PEAKE: ASK AN ASTRONAUT

TIM PEAKE
£20 CENURY

Who's walked in space? Tim Peake, the first British astronaut, shares his experiences from the International Space Station.



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SAM KEEN
£20 DOUBLEDAY

A journey into the mind, from the brain to the soul, this book explores the science of the mind and the human experience.



DO NO HARM

£16.99 WE DE NEFLU & NICOLSON
This is a much-awaited Do No Harm which is both easy to read and has a second part which is a collection of poems and downs of...

TO BE A MACHINE

MARK O'CONNOR
£12.99 GRAY & PETERSON

To be a machine is to use technology to improve the human condition. It makes for an engrossing, witty and a little disturbing read.



PATIENT H69

VANESSA POTTER
£16.99 BLOOMSBURY SIGMA

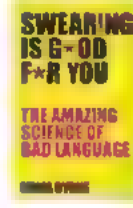
One day, Vanessa Potter started to lose her sight. H69 documents her descent into darkness, and how she began to make sense of her unique condition.



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Why is a knife dangerous? Why is a knife dangerous? God, adds one by one, and asks why we're so easily taken in by pseudoscience in the first place.



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03 SOLVE A PUZZLE

THE PENGUIN BOOK OF PUZZLES
IAN STEWART

MISSING VOWELS

A collection of puzzles involving missing vowels and their consonants. How quick can you decipher them?

NTWB CKLM YSH

LDK NGC L
PPG STHW SL
RNG SN DLM NSTHE PENGUIN BOOK OF PUZZLES
IAN STEWART

ARITHMETIC SQUARE

A collection of arithmetic puzzles. How quick can you solve them?

□	×	□	=	10
□	+	□	=	0
□	-	□	=	12
□	÷	□	=	10

PUZZLE NINJA
IAN STEWART

A PANEL

A collection of puzzles involving a panel. How quick can you solve them?



GET GRAPHICAL

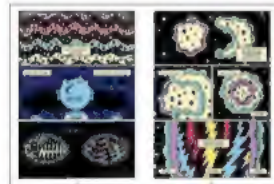
04

This year has seen a wealth of beautiful, science-themed graphic novels and illustrated books. Here are some of our favourites...

CHRISTMAS
BOOKS
GUIDE

OUT OF NOTHING
DANIEL LOCKE & DAVID
BLANDY
£14.99, NOBROW

Combining science fact with dreamlike imagery, Locke and Blandy's eye-popping graphic novel celebrates the ingenuity of the human mind. We travel across centuries from Gutenberg's printing press to Tim Berners-Lee's World Wide Web, via Picasso, Einstein, Rosalind Franklin and more.



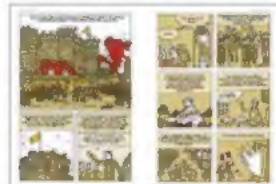
WOMEN IN SCIENCE
RACHEL IGNOTOFSKY
£12.99, WREN & ROOK

Discover (or rediscovers) the work of 50 trailblazing female scientists in Ignotofsky's gorgeously illustrated book. Familiar names like Marie Curie and Ada Lovelace sit alongside lesser-known pioneers such as Maria Sibylla Merian, one of the first and more important entomologists.



GRAPHIC SCIENCE
DARRYL CUNNINGHAM
£16.99, MYRIAD EDITIONS

With his crisp comic art, Cunningham tells the stories of seven scientists who history has rather overlooked. Mary Anning, Alfred Wegener, Fred Hoyle, Jocelyn Bell Burnell... they're names you may have heard of, but Graphic Science underlines the importance of their work.



ANATOMY
HÉLÈNE DRUVERT &
JEAN-CLAUDE DRUVERT
£18.95, THAMES &
HUDSON

A cutaway book of the human body, *Anatomy* elicits gasps of delight in the office. Its flaps and delicate lasercuts allow kids to explore the organs, systems and senses that keep us alive, while the accompanying text provides a nice introduction to human biology.



MYSTERIES OF THE QUANTUM UNIVERSE
THIBAUT DAMOUR &
MATHIEU BURNIAT
£17.99, PARTICULAR BOOKS

performs the tricky task of making quantum physics accessible. Join Bob and his dog Rick on a journey through the world of the very small, talking atoms with Einstein and eating olives with Max Planck.



THE LOST WORDS
ROBERT MACFARLANE &
JACKIE MORRIS
£20, HAMISH HAMILTON

Worried by the way in which natural words (acorn, dandelion, kingfisher, etc.) are disappearing from children's vocabulary, Robert Macfarlane has teamed up with illustrator Jackie Morris to produce this exquisite 'spell book', combining acoustic poems with hand-painted artwork.



Tails of the unexpected

Are bats as important pollinators as bees?

Are pandas virile studs with a taste for group sex?

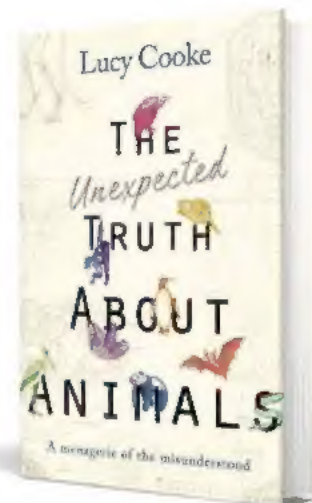
Find out the truth behind some of the strangest animal myths and theories.

'Endlessly fascinating' Bill Bryson



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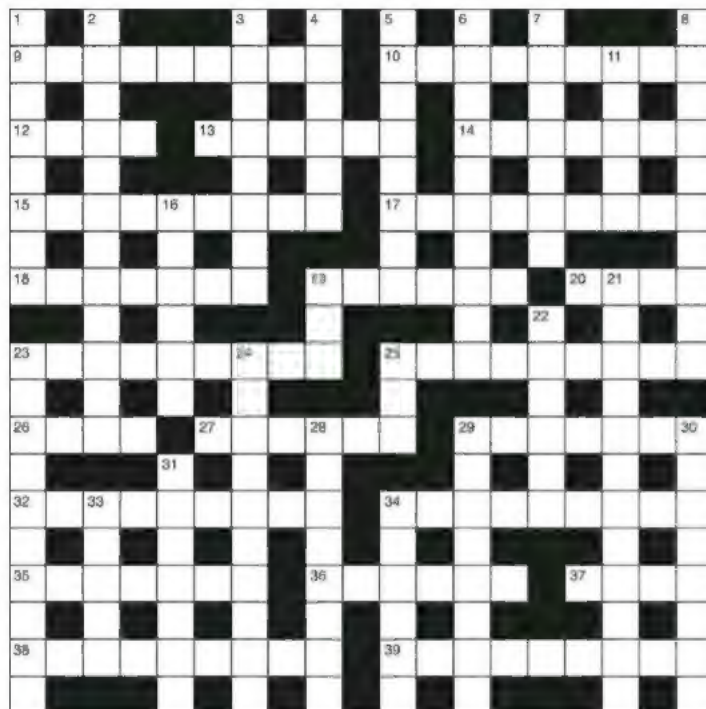


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ACROSS

- 9 Maids came out for conventional attitude (9)
 10 Laugh at English friend taking it for a mineral (9)
 12 Thus get attorney a drink (4)
 13 Jacket right behind conflagration (6)
 14 Lodged a revision for cape in Mozambique (7)
 15 Feature of time, say (9)
 17 Retire one plan to use a compass (9)
 18 Endless series on military exercises for Polyphemus, say (7)
 19 A shade craven (6)
 20 Comedy sketch set in his kitchen (4)
 23 Explosive returned by old sailor (9)

- 25 Claim four worked like a vent (9)
 26 Plant doctor on ship (4)
 27 Peg gets drunk with swine (6)
 29 Idiot is not much of a comedian (7)
 32 Recent ice formation shows restraint (9)
 34 Let animal get confused about food (9)
 35 Allow piece to start for warbler (7)
 36 Nitrogen in advance? Not quite (6)
 37 Feature of each individual (4)
 38 Nice latch, terribly specialised (9)
 39 Appoint to a scientific organisation (9)

DOWN

- 1 Owns CID is returning to form of Judaism (8)
 2 Haphazard entry on computer memory (6,6)
 3 Rearranging did spoil some cells (8)
 4 Female soldier to endlessly astound old and new (6)
 5 Cleaner firm with a trainee getting fuel (8)
 6 Formed rind another way, like a tree (10)
 7 Youngster to drain fish (7)
 8 Show Arctic conditions to be egalitarian (10)
 11 Picture current game differently (5)
 16 Improvise some pasta (6)
 19 Prattle like an ox (3)
 21 King orders tutorial, how to get some energy (8-4)
 22 Girls cooking European salmon (6)
 23 Armies' task, organising source of uranium (10)
 24 Plane used to supply walking stick (10)
 25 Fellow finds a time to blubber (3)
 28 Inexperienced, run away from pest (8)
 29 Musical not so much like Cats – at least some (8)
 30 Gifted, thanks to fast journalist (8)
 31 Diamonds come down in the country (7)
 33 Pick-me-up, often after gin (5)
 34 An eccentric gets one tick (6)

ANSWERS

For the answers, visit bit.ly/BBCFocusCW. Please be aware the website address is case-sensitive.

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MY LIFE SCIENTIFIC

Prof Raj Lada

Helen Pilcher quizzes the founder of the Christmas Tree Research Centre to find out his secret formula for avoiding a carpet covered in pine needles...

In Atlantic Canada, the growing of Christmas trees isn't just something to worry about in the winter – it's a year-round industry that employs 20,000 people

I hate sweeping up Christmas tree needles. Can you help?

Yes. Needle loss is a big problem. In Atlantic Canada where I work, Christmas trees are a \$100m industry. We export three million trees annually, but in the past entire shipments have been lost when the trees lost their needles. It struck me that no one had a clue what was going on. So seven years ago I founded the Christmas Tree Research Centre to find out.

What causes needle loss?

All our work is in our native balsam fir. We've compared trees that lose their needles quickly with trees that keep them for longer, and found many different factors that contribute. You see changes in the

levels of various genes, enzymes, lipids and nutrients. We've identified a key hormone, ethylene, that is involved, as well as over a dozen different volatile compounds that promote needle loss.

Should I water my tree?

Absolutely. It's essential.

Is there anything I can buy to help my tree keep its needles?

It's not in the shops yet, but we've created something that doubles the time your tree will keep its needles. You add it to the water.

Can you tell me what's in it? Or is it a bit like the recipe for Coca-Cola?

All our work is protected by confidentiality agreements, so I have to keep it a secret. Sorry!

Do fairy lights affect needle loss?

Yes, they can actually help. We tested different coloured LED lights and found that white and blue bulbs can increase needle retention by around 120 per cent. Trees also keep their needles longer if they experience a brief cold spell close to cutting. So we've developed technologies to help with that. We could ship our trees around the world three times without them dropping needles.

How about cloning the perfect tree?

We've created something that we call the SMART Christmas tree. We crossed together trees with the best shape and highest needle retention, then used tissue culture methods to make new seedlings. We now have some trees that are over a year old, but they're not technically clones because they contain genetic material from two parents and not from any other source.

Where can I get one?

The embryonic seedlings are currently being mass produced and offered to industry. Next year we anticipate a million seedlings will be ready for planting, but it will be a while before the trees are available to buy. A 150cm balsam fir can take 10 years to grow.

What's the best tree to buy now?

My favourite is still the balsam fir. We always have one. It's a good-looking tree and has a beautiful fragrance.

Have you ever had an artificial tree?

No. I never would.

And finally: star or fairy?

I have a star on my tree, always. ☺

Prof Raj Lada is founding director of the Christmas Tree Research Centre at Dalhousie University, Canada.

DISCOVER MORE

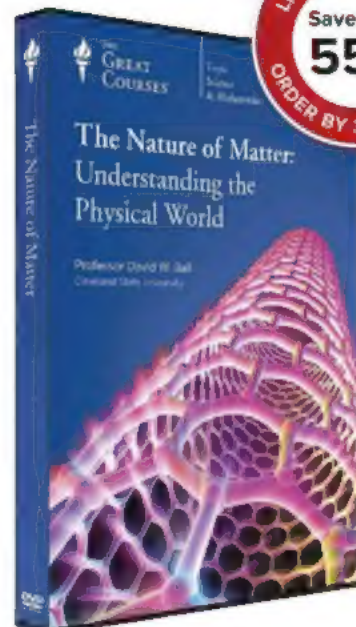
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